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The Use and Design of Flightcrew Checklists and Manuals

John W. Turner
EG&G Dynatrend

M. Stephen Huntley, Jr.
U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe
National Transporation Systems Center
Cambridge, MA 02142

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Final Report

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16. Abstract

A survey of aircraft checklists and flight manuals was conducted to identify impediments to their use and to determine if standards or guidelines for their design were needed. Information for this purpose was collected through the review of checklists and manuals from six Part 121 and nine Part 135 carriers, review of NTSB and ASRS reports, analysis of an ALPA survey of air carrier pilots, and by direct observation in air carrier cockpits.

The survey revealed that some checklists and manuals were difficult to locate and were poorly designed for use in the cockpit environment, the use of checklists by flight crews was not always well defined, the use of checklists interfered with other flight operations, and flight operations often made it difficult to use checklists effectively.

The report contains recommendations for the formatting and content of checklists and manuals, their use by flightcrews, and areas of research relevant to checklist design.

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PREFACE

Following the investigation of the August 1987 crash of Northwest 255, the National Transportation Safety Board (NTSB) concluded that airline training and checking practices do not promote effective use of checklists. One of the recommendations the NTSB made to the Federal Aviation Administration (FAA) was "to determine if there is any type or method of presenting checklists that produce better performance on the part of user personnel."

This report was prepared for the FAA in response to that recommendation. The document describes a study of current checklist designs and practices of Part 121 and Part 135 carriers. Data for this study were collected through an examination of accident/incident reports from NTSB and the Aviation Safety Reporting System, manuals and checklists from Part 121 and Part 135 carriers, and a survey of airline pilots conducted by the Air Line Pilots Association to assess the state of checklist use throughout the industry. Recommendations include guidelines for checklist design.

This paper was prepared for the Biomedical and Behavioral Sciences Branch of the FAA Office of Aviation Medicine by the Operator Performance and Safety Analysis Division of the Office of Research and Analysis at the Volpe National Transportation Systems Center (TSC). The report was completed under the direction of TSC Program Manager M. Stephen Huntley, Jr.; research was the responsibility of John W. Turner of EG&G Dynatrend, an on-site contractor.

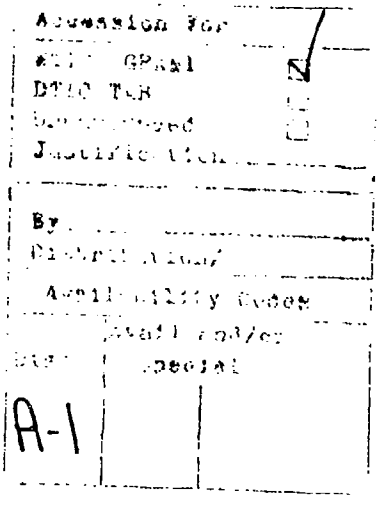


TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES

METRIC / ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

$[(x - 32)(5/9)]\ °F = y\ °C$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

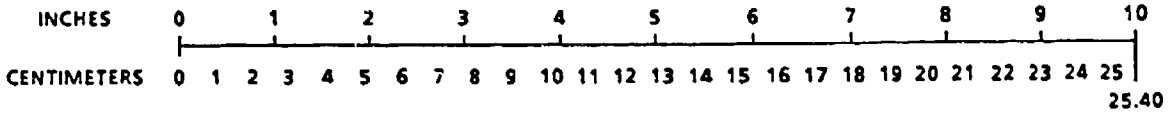
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

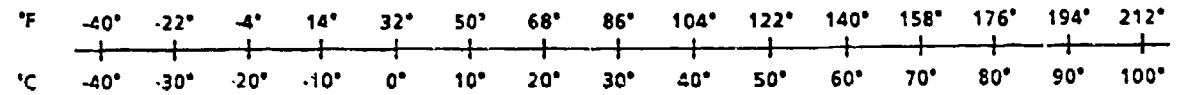
TEMPERATURE (EXACT)

$[(9/5)y + 32]\ °C = x\ °F$

QUICK INCH-CENTIMETER LENGTH CONVERSION



QUICK FAHRENHEIT-CELCIUS TEMPERATURE CONVERSION



For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10 286.

EXECUTIVE SUMMARY

Checklists are valuable, even indispensable, tools of airline safety. Yet it is clear that checklists are being misused or ignored in the industry.

Checklist procedures were not correctly performed in the August 1987 crash of Northwest 255 in Detroit. This conclusion was made by the National Transportation Safety Board (NTSB) after investigating the crash. The NTSB also concluded that airline training and checking practices do not promote effective use of checklists.

Although it is not clear that checklist design contributed to the crash, the NTSB recommended as a Class II Priority Action (A-88-68) that the FAA take steps "...to determine if there is any type or method of presenting checklists that produce better performance on the part of user personnel."

This study was undertaken to help in making that determination. We found that checklists can indeed be improved and have made recommendations to that end. Other recommendations include the need for more training, and the need for review of the FARs concerned with checklists and manuals.

This executive summary describes our sources of information, findings, and recommendations.

Sources of Information

We gathered information for the study as follows:

- Reviewed summaries of NTSB and ASRS accident/incident reports;
- Reviewed selected operator manuals and checklists for Part 121 and Part 135 operators;
- Reviewed results of a pilot survey conducted by the Airline Pilots Association (ALPA)—this survey explored pilot use of checklists;

Other sources included:

- Meetings with an NTSB investigator and representatives of two regional carriers;
- Meetings with the Air Transport Association (ATA) Flight Crew Checklist Working Group;
- Jumpseat rides on regional and major carriers to observe checklist performance in an operational setting;
- Visits to two corporate aviation departments to discuss checklist issues;
- Examination of guidelines in human factors handbooks and military specifications (MIL SPECS) concerning the design of checklists and manuals.

Findings

The NTSB report summaries included the period from 1/83 to 10/86. During this time, 21 accidents/incidents of multi-engine aircraft occurred in which a defective or a misused checklist was involved. In five of these cases, a checklist was not used at all. (In 17 of these cases, the aircraft was badly damaged or destroyed.) The ASRS report summaries included 195 reports of occurrences involving checklists over the past five years. The types of errors found in the ASRS report summaries were confirmed by an ALPA survey, meetings with representatives of NTSB, ATA, and regional carriers; and by jumpseat rides on various aircraft. Corporate on-site visits provided information on checklist technology in selected applications. The following problems were identified:

- A breakdown in crew coordination or procedures in checklist use contributed to by a lack of training. There was also a lack of clear direction to crews in the use of checklists in many cases.
- Interruptions were a cause of checklist misuse. There were external interruptions to the use of a checklist by a flight crew and operational tasks being interrupted by the necessity to use a checklist. These findings were confirmed by the ALPA survey.
- The design, organization, and contents of checklists and manuals were often nonstandard. There were missing, inconsistent, and incorrect procedures. Checklists were sometimes not in the order in which they were to be performed. Items, and sometimes whole sets of operationally relevant procedures, were not carried over from Airplane Flight Manuals (AFM) to checklists. Checklist actions some-

times were different from the required procedure in the AFM.

- Readability varied widely, even within the same company's checklists. Type size and clarity were dissimilar and the need for guidelines was apparent.

- Color coding of checklists was seldom used although it could facilitate finding critical checklists.

- The use of the terms "ABNORMAL" and "EMERGENCY," as they applied to checklists, was inconsistent. What one manufacturer might call an ABNORMAL procedure, another called an EMERGENCY. A clear definition of each term promulgated throughout the industry might promote standard use and eliminate confusion.

- Emergency checklists were difficult to retrieve when needed. They were often carried in poorly tabbed manuals in flight bags.

- Heads-down time is reported as increasing with the use of checklists on CRTs. This also pertains to the necessity to reprogram cockpit computers for changes in flight plans.

RECOMMENDATIONS

Recommendations address the need for improved checklists and manuals and more training in the use of checklists. These recommendations are detailed below.

- Design guidelines for checklists and flight manuals should be developed as follows (also see Appendix A).

Checklists

"Normal" checklists should:

- Include only operationally pertinent items;

- Be listed in the order to be performed;

- Have safety critical items such as gear and flaps as final items listed prior to takeoff and landing;

- Have sufficiently large type with the necessary clarity of print and contrast to ensure good readability in all cockpit lighting conditions;

- Include no more individual checklists than can fit on a single, easily stowed card.

"Emergency" checklists should:

- Be readily accessible in cockpits;

- Be available on a card as well as in a manual; on the reverse of the "Normal" checklist card, if possible;

- Have a standard order of presentation for all aircraft in a company's fleet, so that individual checklists can be located easily;

- Have clear visual separation of checklists with titles in boldface, all caps, and in type two points larger than the text, for easy identification;

- Be no smaller in type than a well-designed "Normal" checklist, and larger if space permits;

- Contain only those items needed to combat the emergency. These checklists should be easy to understand and execute.

Manuals

Procedures specified in manuals for checklist use should:

- Clearly define crew checklist roles in different phases of aircraft operation;

- Require specific responses wherever the "AS REQUIRED" response is written; for example, "FLAPS....20°," "ANTI ICE....OFF (or ON)";

- Require dual response only to the highest priority safety critical items;

- Require immediate replacement of checklists worn to the point of reduced readability.

Requirements for the format of manuals should:

- Specify a clearly referenced and standardized table of contents;

- Specify standardized, color-coded tabs for each checklist section and subsection with an alphabetized index as the first page after the tab.

- Initial and recurrent training should be required in checklist use.

- Review of FARs should be conducted to determine the need for:

  - A clear definition of "NORMAL," "ABNORMAL," and "EMERGENCY" to establish uniform checklist classification by manufacturers and airlines;

  - A requirement that all operators, regardless of size, meet the same standards for manuals and checklists.

Research and development should be conducted to:

- Establish quantitative and behavioral criteria for checklist accessibility and readability;

- Develop and evaluate the usefulness of a standard format organization, and table of contents for aircraft flight manuals;

- Evaluate the use of all caps vs. mixed case lettering in checklist design;

- Develop and evaluate the use of a standard terminology for controls, displays, and in-flight operations in checklists and flight manuals;

- Evaluate the utility, safety benefits, and limits of audio checklists, checklists on CRTs, and checklists with artificial intelligence features, both in a laboratory setting and in an operational context; (There is currently an audio checklist design available from Heads-Up Technology that will be the subject of a study by United Airlines.)

- Evaluate the benefits of color coding and different font styles on checklist readability for electronic as well as paper checklists;

- Evaluate the operational feasibility of checklist interlocks that would prevent aircraft takeoff without completion of safety critical items;

- Evaluate the utility, safety benefits, and limits of mechanical checklists such as those used by American Airlines for "BEFORE TAKEOFF" and "BEFORE LANDING.";

- Develop and evaluate a prototype checklist for Parts 135 and 121 use. This list would be developed as an example of how human factors principles in the use of formatting, font size, and color coding can be applied to improve checklist design;

- Determine the influence of memory items on emergency checklists on the speed and accuracy with which emergency procedures are performed.

THE USE AND DESIGN OF FLIGHTCREW CHECKLISTS AND MANUALS

1. INTRODUCTION

Checklists have been used, in one form or another, since the beginning of manned flight, and certainly since the inception of the airline industry. Even the most rudimentary reminders to assure aircraft readiness were an early form of checklist. With the increasing complexity of aircraft, the ability of the pilot(s) to accomplish all the items necessary for safety without some type of checklist was diminished, and with the advent of larger and multi-engine aircraft, a more formal checklist became necessary to assure completion of the multitude of items to be checked. However, as aircraft grew larger and more complex, as checklists grew in size, and as traffic increased, interferences to checklist use also increased, with resultant increases in the probability that errors would be made in the use of checklists and checklist-driven procedures. ASRS reports, data in NTSB files, pilot reports, and direct cockpit observations indicate that checklists can be misused easily and are sometimes even ignored. There is much concern throughout the industry and some empirical support that such misuse or lack of use has contributed to the occurrence and severity of aircraft accidents.

1.1 REASON FOR THE STUDY

Following its investigation of the crash of Northwest Flight 255 in Detroit, in August 1987, The National Transportation Safety Board concluded that "...the flight crew did not perform the checklist procedures in the manner prescribed in the company's *Airplane Pilot's Handbook*." They noted that training and checking practices currently in use by the airlines do not promote effective use of checklists.

Although it is not clear that checklist design was an important contributor to the Flight 255 crash, the NTSB did include among the seven recommendations produced by their investigation, the Class II priority Action (A-88-68) that the FAA take steps "...to determine if there is any type or method of presenting checklists that produces better performance on the part of user personnel."

The objectives of this study were: a) to identify conditions that interfere with cockpit crews executing or verifying normal and abnormal cockpit procedures through the use of checklists; b) to determine the need and nature of FAA action to promote good checklist practices; and c) to determine requirements for research on the design and use of cockpit checklists.

1.2 APPROACH

The following processes were used to accomplish the objectives of the study:

- Determine the contents and readability of current checklists and handbooks;
- Identify operational conditions that interfere with checklist use;
- Identify flight crew practices that interfere with checklist use;
- Identify design, procedural, operational, and flight crew characteristics that promote good checklist use.

1.3 PRODUCTS

- Specification and discussion of conditions that interfere with good checklist practices.
- Guidelines for checklist design and evaluation.
- Recommendations for further study in areas of checklist design where more information is required.
- Recommendations for changes in FARs to promote improved use and design of checklists.

2. METHODS

We used the following means of gathering information for this study.

2.1 NTSB AND ASRS REPORT SUMMARIES

Relevant NTSB and ASRS accident/incident reports were reviewed to identify conditions that could promote the misuse of checklists, and to identify operational errors that may have resulted from checklist misuse.

2.2 STUDY OF PARTS 121 AND 135 OPERATOR INFORMATION

A sample of checklists cards and expanded checklists in handbooks from prominent Parts 121 and 135 air carriers were examined:

- To identify design and implementation practices that should be promoted;
- To determine if there was a need for guidance in the design and implementation of checklists;
- To identify design and implementation issues that should be addressed by research, regulations, or recommendations to the industry.

2.3 ALPA SURVEY

The Airline Pilots Association (ALPA) surveyed line pilots to request their experiences and opinions concerning the checklists they use. It was expected that the information provided by this survey would indicate the operational significance of various characteristics of checklist design and design options, serve to identify safety issues that we may have missed in our analyses, and identify differences in pilot opinion regarding checklist issues.

2.4 ADDITIONAL SOURCES OF INFORMATION

- Discussions with an NTSB investigator and representatives of two regional carriers.
- Meetings of the ATA Flight Crew Checklist Working Group. This group was convened to provide a forum between the FAA group responsible for writing the manual and checklist guidelines for the *Draft Inspectors' Handbook* and industry representatives.
- Jumpseat rides on regional and major carriers to observe use of checklists by crews, and to ascertain conditions that interfere with checklist use.
- Visits to two corporate aviation departments to discuss checklist technology used in corporate cockpits, and to elicit opinions on that technology.
- Examination of guidelines for manual and checklist construction in human factors handbooks and military specifications (MIL SPECS).

3. FINDINGS AND DISCUSSION

3.1 NTSB REPORTS SUMMARY

From the beginning of 1983 to 10/7/86, there were 21 accidents/incidents (involving multi-engine airplanes) investigated by the NTSB, in which the improper use of a checklist or a defective checklist was suspected. In 24% (five) of these, the checklist was not used at all. Of the remainder, a manufacturer's checklist was found to be inadequate in one case, and in the other cases the checklists were not properly followed.

The danger of checklist misuse is seen in the results of the accidents, 81% (17) of which resulted in substantial damage or destruction of the aircraft. A brief summary of the NTSB investigations follows.

- Detroit, MI, 1/11/83 - United Airlines DC-8-54F - aircraft destroyed - three crew fatalities - improper trim setting caused loss of aircraft control - might have been compounded by unqualified 2nd officer occupying 1st officer position during takeoff - checklist not followed.
- Bryce, UT, 4/2/83 - Republic DC-9-82 - both engines flamed out due to fuel starvation - emergency declared - engines restarted - checklist not followed due to distraction.
- Little Rock, AR, 4/13/83 - Central Flying Service Beech BE-58 - substantial aircraft damage - gear up landing excessive workload and checklist not used.
- Luke AFB, AZ, 5/28/83 - Republic DC-9-31 - forced landing caused by engine flameout due to fuel exhaustion - a tripped fuel quantity circuit breaker was not noticed during the preflight checklist - checklist not followed.
- Blountville, TN, 10/28/83 - Atlantic Southeast Embraer EMB 110-P1 - substantial aircraft damage - 16 minor injuries - aircraft landed gear up due to indication of one gear not down and locked - no confirmation made on indication problem - checklist not followed.
- Longview, TX, 2/29/84 - Mid America Airways, Inc. Beech E-55 - substantial aircraft damage - two minor injuries - total loss of power, forced landing - took off on almost

empty auxiliary fuel tanks, plenty of fuel in main tanks - checklist not followed.

- Grand Island, NE, 6/29/84 - Pioneer Airways, Inc. Swearingen SA 227-AC - minor aircraft damage - loss of control on takeoff roll, struck runway light - left prop on start locks - checklist not followed.

- Selawik, AK, 10/16/84 - Ryan Air Service, Inc. Beech 3NM - substantial aircraft damage - gear up landing - checklist not followed.

- San Antonio, TX, 12/24/84 - K. E. Cohlima Beech 95-C55 - substantial aircraft damage - gear up landing - checklist not followed.

- Holly Springs, MO, 2/8/85 - Professional Aviation Beech 58 - substantial aircraft damage - gear up landing - couldn't lower gear manually because the pilot couldn't unstow the crank - checklist not followed.

- Berkeley, MO, 2/13/85 - Britt Airways, Inc. Swearingen SA 226-TC - both engines quit on final due to ice ingestion - plane landed without damage - nothing on the checklist concerning the use of auto-ignition in freezing outside air temperatures.

- Williston, ND, 4/7/85 - Pioneer Airlines, Inc. Swearingen SA 227-AC - substantial aircraft damage - landed gear up - improper use of checklist.

- Potsdam, NY, 5/17/85 - Sair Aviation Piper PA-31-350 - substantial aircraft damage - gear up landing - checklist not followed.

- Atlanta, GA, 5/19/85 - Basil Aircraft Services Embraer EMB-110-P1 - substantial aircraft damage - collision with parked aircraft on rollout - insufficient hydraulic brake pressure due to incorrect monitoring of warning annunciator light and use of incorrect procedure - checklist not used.

- Nashville, TN, 5/31/85 - General Aviation, Inc. Gulfstream G-159 - aircraft destroyed - two crew fatalities - loss of control after engine loss on takeoff, prop didn't feather - H. P. cock levers not in "cruise lockout" position - item not done on checklist before takeoff.

- Dallas, TX, 8/7/85 - Air Midwest, Inc. Fairchild/Swearingen SA 226-TC - substantial aircraft damage - gear up landing - could have manually extended gear - didn't use checklist.

- Orlando, FL, 4/22/86 - Craig Air Center Beech 95-B55 - substantial aircraft damage - gear up landing - late extension of gear, aircraft landed on gear doors - checklist not followed.

- Indianapolis, IN, 7/9/86 - PDQ Air Service Beech BE-58 - substantial aircraft damage - gear up landing - checklist not used.

- Jacksonville, FL, 10/7/86 - Top Flight, Inc. Ted Smith Aerostar 600 - substantial aircraft damage - gear up landing - checklist not used.

- Santa Barbara, CA, 10/30/86 - Wings West Airlines, Inc. Fairchild/Swearingen SA-226-TC - substantial aircraft damage - one serious injury, two minor injuries - gear up landing - prop fragmented and punctured passenger compartment - gear warning horn circuit breaker deliberately pulled and gear called for but not extended - checklist not followed.

- Florence, SC, 2/5/87 - Atlantis Leasing, Inc. Swearingen SA-226-TC - substantial aircraft damage - gear up landing - checklist not followed.

In one of these cases, the incident was directly attributable to the use of an inadequate manufacturer's checklist. In another case, inflight distractions contributed to a lack of conformity to checklist procedures. One report cited excessive workload as a factor. In another case, the NTSB cited the company management for "improper emergency procedures training" of its pilots.

Of the 21 cases reviewed, 20 involved lack of conformance with the FARs regarding checklist use. In the cases not involving extenuating circumstances, it is not possible to ascertain the reason for nonconformity from the information we have. But, the large proportion of instances of nonconformity indicates that this problem may be as great a problem as is checklist design, if not greater.

3.2 ASRS REPORTS SUMMARY

ASRS reports provide a rich source of information regarding problems in aviation. They are submitted on a voluntary basis by pilots, controllers, and others in the operational side of the industry. Because submissions are voluntary, the contents of this database should not be considered representative enough for use in describing all errors and problems that occur in the cockpit. The crews report the problems that they want to report. Nevertheless, there is no reason to doubt that the problems that are reported did in fact occur.

Those submitting reports are asked to identify themselves for purposes of phone contact by ASRS for amplifying information; however, all reports are deidentified shortly after being received. The reports are available for research on specific subjects. We requested reports on any occurrences involving checklists over the past five years. We received summaries of 195 reports that were relevant to our study. A summary of each of those is included in Appendix C. The following shows categories of errors made and gives examples of each.

- Sixty-five were cases of checklist items being missed or incorrectly performed by the crew:
  - Engine flamed out at altitude from fuel exhaustion. Declared an emergency. Crew had not turned on all boost pumps as instructed in the checklist.
  - Control lock still installed on the yoke during takeoff. Aborted flight 40' in the air after noticing lack of control response.
  - Altimeter mis-set by 1", not checked by crew, altitude overshoot on short final, warned by the GPWS.
- Ten had nothing on the "before landing" checklist to accomplish the required action:
  - Aircraft landed with fuel badly out of balance limitations, no item on the checklist to check fuel pump configuration.
  - Altitude undershoot in climb. The reset of the altimeter at 18,000' to QNE (the setting of altimeters to 29.92 at 18,000 feet and above) was not on the checklist.
- Eleven involved poorly designed checklists or manuals:
  - Checklist called for throttle to be pulled out 1/2" on start, whether engine was hot or not. On start, the pilot could not control the plane and hit the fuel pump (the throttle should be closed for hot-engine starts).
  - Altitude overshoot on climbout. Checklist procedure has altimeters reset at 10,000' in the climb - far too late when assigned altitude is below that.
- Six had no checklist to use:
  - Aircraft failed to pressurize because neither air conditioning pack was functioning. No abnormal checklist was available to cover that condition (this was on a wide body airplane).
  - Aircraft landed gear up. No checklist, and the pilot didn't use a GUMP check.
- Twenty indicated that the appropriate checklist was not used by the crew:
  - At 1,500' in climb, an experienced Captain cut the fuel to both engines (two-engine aircraft) in response to an annunciator light for right engine EEC. Copilot (PF) reported that the Capt. did not refer to the abnormal checklist or coordinate with him prior to the action.
  - Crew looking for unfamiliar airport, didn't do the final checklist, and landed gear up. Warning horn didn't sound until the flare - too late.
- Seventy-four showed poor crew coordination in the use of a checklist:
  - Engine shut down needlessly in flight during performance of electrical abnormal checklist procedures. First Officer started APU for backup - Captain saw the low oil pressure light at APU start and mistook it for an engine low oil pressure light, shutting down the engine. First Officer didn't inform Captain of starting the APU, and Captain didn't confirm engine low oil pressure with First Officer before shutting down the engine. Emergency

declared with unscheduled landing.

- Aircraft taxied across an active runway after instructions to hold short. First Officer got instructions, assumed Captain had heard them and started doing the checklist, heads-down.

- Early turn to a SID (Standard Instrument Departure) heading with traffic conflict. Crew busy reading the checklist and not backing each other up.

- Eighteen involved the use of an incorrect or incomplete procedure as prescribed by the checklist:

  - Aircraft departed 10,000 lbs. light on fuel. New fueling procedure provided no clear means of fuel load verification for fuelers or crews.

  - First Officer lost his instruments and the radar as he was about to penetrate a line of cells. Captain and Second Officer were doing an electrical abnormal checklist which knocked off the instruments and radar.

- One-hundred thirteen involved an interruption or distraction, either from the use of a checklist, from operational matters, or from some extraneous event:

  - Overshot altitude by several thousand feet, inexperienced crew busy doing the checklist and working ATC radios.

  - Altitude overshot on descent. Between FL310 and FL180, crew had five speed changes and two heading changes. Subsequently they had three more speed changes, two more heading changes, and three runway changes - the last occurring at 400' on final. The altimeter of the pilot flying did not get set properly.

  - Aircraft almost departed with a spoiler extended. Crew taxiing with one engine shut down. Controller advanced their take-off position. Rushing to complete everything and missed the annunciator light for the extended spoiler. Caught by crew in a following aircraft.

(The percentages add up to more than 100% because many samples involved multiple considerations.)

Since these reports are provided to NASA/ASRS on a voluntary basis, information which would not otherwise be available is provided about problems in aviation. Although they may not be completely representative of the industry, these findings help to point out the variety of the problems encountered with regard to checklist misuse.

SUMMARY OF FINDINGS

- CHECKLIST USE

  In 43% of the reports studied the crew had either not used the checklist at all, or had missed important items on the checklist.

- CHECKLIST AND MANUAL DESIGN

  These factors accounted for 20% of the reports. Design problems included items missing from checklists and inaccurate or incomplete procedures which could lead to potentially dangerous practices.

- TRAINING

  Thirty-eight percent of the reports involved inadequate crew coordination. This could indicate an absence of instructions in the AFM or inadequate training in checklist use.

- INTERRUPTIONS

  Interruptions accounted for 58% of the reports. There was about an even division of the following two types of disruptions:

  - events, such as ATC calls, interrupting the crew's use of checklists;

  - the necessity to read a checklist interrupting an operational task, such as maintaining a position in a departure queue.

3.3 PART 121 AND PART 135 CHECKLIST AND MANUAL REVIEW

We reviewed six Part 121 operators' and nine Part 135 operators' manuals and checklists as one means of identifying good and bad aspects of current air carrier checklist practices. These materials were not

randomly selected and so are not assumed to be representative of what is used in the industry. They are, however, examples of materials in daily use by major carriers.

3.3.1 Policy and Procedures for Checklist Use

All of the Part 121 operators studied specified some policy regarding the use of checklists for their crews to follow. Some had very specific guidelines regarding who was to read each checklist, by what phase of flight it was to be accomplished, in what manner it should be read (e.g., challenge/response or silent), whether with single or dual response, and what responses should be given in lieu of "CHECKED" or "AS REQUIRED." Others only used phrases such as "Checklist use is mandatory.", and "Safe operating procedures are not overlooked while giving attention to the checklist." Still others merely specified who should read each checklist and at what phases of flight they should read it. One example of this is the airline specifying that the First Officer should read all "Normal" checklists while the aircraft is stationary, and the pilot not flying should read all "Normal" checklists while the aircraft is in motion.

Of the Part 135 operators, only one did not have some sort of policy for the crews to follow. The other policies ranged from numbered notations on each checklist margin as to who should answer each challenge, to the very detailed and explicit directions from one of the carriers to their crews. Their policy statements were as good as some of the larger carriers, and better than others.

One carrier was unique among all the carriers studied in that it specified that its "Normal" checklists were to be used as "work" lists rather than "done" lists. Rather than the items being accomplished and then checked for completion by the use of the checklist, it specified that the challenge be read, the item be accomplished, and then the response be given, indicating accomplishment. While this is sometimes the case with "Emergency" checklists, and often the case with "Abnormal" checklists, it is not usual with "Normal" checklists.

Three issues arise with policy and procedures for checklist use. They are:

- When should checklists be used?

  The time a checklist is to be used is spelled out, in part, in the name of the checklist; e.g., "BEFORE TAXI," "BEFORE LANDING," etc. Some of the carriers in their policy statements are even more specific; prescribing in what phase of flight, and at what point in the phase of flight a checklist is to be read. In a number of the cases we studied, however, this was left to the pilot.

- Who should read/respond to the checklist items?

  This was handled by the airlines in a multitude of ways. Some addressed the issue with a detailed policy statement stating which pilot should read which checklist and which pilot should respond. Others made a margin notation on each checklist with a number designating which pilot was to respond. Others did not address the issue.

  Another point in this issue is that of dual response. This involves items which must be checked and responded to by at least two crewmembers, frequently at busy phases of flight; some airlines have items to which all members of a three-person crew must respond. This creates a division of attention for the pilot flying. Of the Part 121 carriers studied, most used some dual response items in all "Normal" checklists, whereas, of the Part 135 carriers, only one did. One of the Part 121 carriers limited dual response items to "GEAR" and "FLAPS," and then only on two checklist procedures; "FLAPS" on the "TAXI" procedures list, and "GEAR" and "FLAPS" on the "LANDING" procedures list. Limiting dual response requirements to one or two items reduces the amount of time when both crewmembers have their heads down, yet provides an additional level of attention to ensure that the gear and flaps are positioned properly for high-risk phases of flight.

- How should the checklists be used?

  This issue was not addressed by many of the airlines. And those that did address it were not always consistent. As an example, let us use the checklist response "AS REQUIRED." One carrier did not use any "AS REQUIRED" responses on some of its aircraft, but did on others.

The general issue of requiring a specific response in lieu of the "AS REQUIRED" shown on a checklist was addressed. The request for a specific response requires that the crew look at the item being checked in order to give that response. The discretion to answer "AS REQUIRED" permits careless checking and poor checklist habits. Six of the Part 135 carriers allowed the use of the "AS REQUIRED" response, as did two of the Part 121 carriers. The handbooks of three of the Part 121 carriers stated that a specific answer should be substituted for "AS REQUIRED," and one Part 135 carrier very specifically disallowed "AS REQUIRED" and specified precise responses. Examples of this would be "12 QUARTS," "ON," etc. One major carrier eliminated the problem by not having "AS REQUIRED" as a checklist response.

3.3.2 Alphanumerics

The comparison of print size and letter case used in the text of the checklists revealed a number of problems. This was true of both the Part 121 carriers and the Part 135 carriers.

"Normal" checklists for all but one of the Part 121 carriers and 50% of the Part 135s were in 10-point type, and usually in all caps (see Figure 3-1). This was normally quite legible, but in some cases, the quality of print was poor and that affected the legibility considerably. MIL SPECS (MIL-C-81222C and MIL-C-38778A) recommend the use of 12-point type for the body of the text. One of the Part 121 carriers used six-point type, mixed case (see Figure 3-1), their checklists were difficult to read, and it would have been easy to lose one's place if distracted by other operational requirements. In the Part 135 checklists, of the 50% that did not use 10-point type, the type size varied down to seven-point, mixed case, and was not very legible. One set of regional checklists incorporated a V speed table in five-point type (see Figure 3-1), and the numbers were almost illegible.

"Abnormal" and "Emergency" checklists showed even greater inconsistency in alphanumeric sizes than the "Normal" checklists. One major carrier in their "Normal" checklist used 10-point type, all caps. Yet their "Abnormal" checklist, although kept in a well-tabbed pilots' handbook and easy to find, was in six-point type and mixed case, and difficult to read. Their "Emergency" checklists were presented on a color-coded paper card with one side in 10-point type, the other side in eight-point type. Both sides were in all caps. The eight-point was slightly less legible than the 10. It appears that this combination of type was used in order to include all the checklist items on a single card. Another Part 121 carrier, although using legible 10-point type in their "Normal" checklist, used eight-point type and all capitals with the letters spaced closely together for their other checklists.

Among the Part 135 checklists, the same sorts of problems, but more pronounced, were often seen. One of the regionals used legible 10-point type for the "Normals" and then reduced to seven-point type for their "Emergency" checklists. The reverse was found in another case, with the "Normal" checklists in the small, difficult-to-read print.

The practice of using smaller, less legible type for "Abnormal" and "Emergency" checklists than for "Normal" checklists was found amongst both major and regional carriers. Since these are checklists which are used under conditions of stress, and often with poor illumination, they should be as legible as possible, and surely not smaller than the "Normal" checklists.

Clear, 10-point type presents a legible checklist, and is used by a number of the major carriers we studied. However, with type larger than 10-point, as is recommended by the aforementioned MIL SPECS and by the *Human Engineering Guide to Equipment Design*, the checklist page becomes larger, or more pages are necessary, and checklist stowage and handling becomes more of a problem.

3.3.3 Method of Presentation

All of the Part 121 carriers studied used paper checklists for at least the bulk of their "Normal" checklists. By contrast, only 50% (five) of the Part 135 operators did this. One Part 135 carrier had its "Normal" checklists on a laminated card, and the other four were in either a manual or a separate checklist booklet.

One of the major carriers studied used paper checklist cards for all but the "BEFORE TAKEOFF" and "BEFORE LANDING" checklists. These were mechanical, in either a lighted slide or a lighted toggle switch configuration, depending on the airplane type. They did have a printed backup in the Operating Manual to cover the possibility of a mechanical checklist malfunction. The use of these mechanical checklists for this limited use was re-

FIGURE 3-1. TYPEFACE SAMPLES

BEFORE STARTING ENGINES

LOG BOOKS AND SEL.....CHECKED
* RUDDER PEDALS AND SEATS.....ADJUSTED AND LOCKED
* WINDOWS.....CLOSED AND LOCKED
O_2 PANELS/MASKS/INTERPHONE/ GOGGLES.....SET AND CHECKED
EMERGENCY LIGHTS.....ARMED
* PROBE HEAT.....CAPT
* WINDSHIELD ANTI-ICE.....ON
ANTI-SKID.....OFF
PRESSURIZATION.....AUTO (UP) AND SET
* AIR COND SHUTOFF.....AUTO
* FLIGHT GUIDANCE PANEL.....SET AND CHECKED
* FLT INSTR/SWITCHES/BUGS.....SET AND CROSSCHECKED
* FUEL PANEL/QUANTITY AND DISTRIBUTION.....SET/___LBS AND CHECKED
GEAR HANDLE AND LIGHTS.....DOWN AND GREEN
* TRANSPONDER.....SET
* STABILIZER TRIM.....SET
SPOILER LEVER.....RET
THROTTLES.....CLOSED
FUEL LEVERS.....OFF
FLAPS/SLATS.....UP/RETRACTED
* AILERON/RUDDER TRIM.....ZERO/ZERO
* PARKING BRAKE/PRESSURE.....PARKED/NORMAL
* SHOULDER HARNESSES (If Operative).....ON
* FLIGHT FORMS.....CHECKED
* NO SMOKING SIGNS.....ON
* SEAT BELT SIGNS (5 Minutes Prior To Departure).....ON

PRIOR TO ENG START OR PUSH-OUT

GALLEY POWER.....OFF
ENGINE IGNITION.....CONTIN
FUEL PUMPS.....ON
AUX HYDRAULIC PUMP.....ON
ANTI-COLLISION/EXTERIOR LIGHTS.....ON/AS REQUIRED
DOOR ANNUNCIATORS.....OUT
AIR CONDITIONING SUPPLY SWITCHES.....OFF

10 POINT

MD-80

EXTERNAL ELECTRIC & PNEUMATIC SOURCE - START

PNEUMATIC X-FEEDS ..... BOTH CLOSED
PNEUMATIC AIR SOURCE ..... CONNECTED & ON
PNEUMATIC X-FEEDS ..... OPEN
PNEUMATIC PRESSURE (25 PSI MIN) ..... CKD
COMPLETE - BEFORE START CHECKLIST

AFTER ENGINES STABILIZED
PNEUMATIC X-FEEDS ..... BOTH CLOSED
ELECTRIC POWER ..... *CKD
EXTERNAL ELECTRIC & PNEUMATIC ... DISCONNECTED
COMPLETE - AFTER START CHECKLIST

BEFORE START
BRAKES ..... SET
WINDSHIELD HEAT ..... *ON
FUEL PUMPS ..... *(AS REQ)
CABIN PRESSURE CONTROLLER ..... *SET
AUX HYDRAULIC PUMP & PRESSURE ..... *ON & CKD
CIRCUIT BREAKERS ..... **CKD
AUTOLAND ..... CKD
RADIOS, ALTIMETERS & FLIGHT DIR .... **CKD & SET
FUEL & OIL ..... **(QUANTITIES) & RESET

IGNITION ..... ON
SEAT BELT SIGN ..... ON
BEACON ..... ON

AFTER START
ANNUNCIATOR ..... CKD
IGNITION ..... *OFF
ELECTRIC POWER ..... *CKD
APU AIR ..... *(AS REQ)
AIR CONDITIONING SUPPLY SWITCHES ..... *AUTO
PNEUMATIC X-FEED ..... *ONE CLOSED
TRANSFER PUMP & HYDRAULIC SYSTEMS .... *ON & CKD

6 POINT

B99 SPEEDS-KIAS

	30% Flaps		0% Flaps				100% Flaps
Weight	V_R	V_{50}	V_R	V_{50}	V_{XSE}	V_{YSE}	V_{REF}
10900	98	94	103	98	103	114	97
10000	94	91	99	95	101	111	93
9000	92	89	96	90	98	108	88
8000	92	89	96	90	95	105	83

C99 SPEEDS-KIAS

	30% Flaps		0% Flaps				100% Flaps
Weight	V_R	V_{50}	V_R	V_{50}	V_{XSE}	V_{YSE}	V_{REF}
11300	102	116	107	115	91	115	107
11000	101	115	106	114	91	114	106
10000	101	111	102	111	91	111	103
9000	101	107	99	109	91	109	100
8000	101	105	99	108	91	108	98

5 POINT

ported on very favorably by the pilots using them during our cockpit observation on that airline.

One Part 121 airline used paper checklist cards for "Normal," "Abnormal," and "Emergency" checklists, and stowed them all in the cockpit. The size of the paper checklist cards studied varied, and is important only in that it must be large enough to hold legible checklists, and small enough to be stowed readily in some location in the cockpit.

Those studied ranged from a fourfold 10 7/8" x 5 1/2" to a no-fold 8 1/2" x 11." The former was very crowded and difficult to read, whereas the latter was very legible. In some cases, the large cards designed to be no-fold were observed to have been folded by the crews, presumably for convenience.

Most of the carriers kept their "Abnormal" and "Emergency" checklists in manuals or booklets of some sort. All of the Part 135 manuals studied, and some of the Part 121 manuals, lacked tabbing for quick reference and easy identification. This lack of tabbing could provide an added impediment to a crew at a time when they are already dealing with a situation other than normal. The use of a booklet, capable of being stowed in the cockpit, is preferable to a manual stowed in a flight bag from the standpoint of accessibility. Handier yet would be a separate card of "Emergency" checklists stowed in the cockpit.

If a booklet or a manual is to be used, it should be properly tabbed for quick reference. Each major section should be tabbed with the name of the section, and each subject within a section tabbed to correspond with the appropriate subject shown in the section index. The section index should be on the first page of each section, following the tab. If the manual contains a section on aircraft systems, there should be a tabbed subsection for each individual system, (e.g., engines, flight controls, etc).

3.3.4 Color Coding

Two of the Part 121 carriers, and three of the Part 135 carriers used color coding for easy identification of "Abnormal" and "Emergency" checklists. There have been instances cited in ASRS reports in which crews have had difficulty in locating "Emergency" checklists. Human factors research indicates that color coding can be effective in helping to identify emergency checklists. Advisory Circular 25-11, dated 7/16/87 recommends red be used for the most serious conditions, and yellow be used for abnormal conditions of a less immediate nature.

3.3.5 Memory Items

Memory items on "Emergency" checklists have been a point of difference in corporate philosophies for years. Of the Part 121 "Emergency" checklists reviewed, all had some form of memory items; those items which the crew must commit to memory for performance in an emergency situation, to bring the emergency under control before referring to the checklist. One major carrier, which was not included in our study, has adopted the philosophy that memory items are not only not necessary, but may precipitate a mistake through too much haste. They have eliminated memory items from their "Emergency" checklists, and instead use them as lists from which to work. This is not the case with most carriers. They range from having memory items for all the initial steps in all the "Emergency" checklists to a very limited number of items on a small number of checklists. The former is more common. The latter is represented by one of the Part 121 operators in our sample. Only three of their "Emergency" checklists contained memory items: "ENGINE FAILURE," "ENGINE FIRE," and "ENGINE TAILPIPE FIRE," and each list contained only one memory item. In all three cases the item was the same, "THROTTLE,CLOSE.....CLOSE."

The Part 135 carriers were apparently not much different from the Part 121 carriers in this regard. Of the 10 studied, eight used memory items. One did not require them, and the tenth provided no "Emergency" checklists for study.

3.3.6 Manual and Checklist Contents and Organization

The Part 121 carriers generally exhibit more legible and professional-looking checklists and manuals than their Part 135 counterparts. However, there is still room for standardization and improvement. Despite the generally high quality of professional standards and performance of Part 121 scheduled carrier pilot groups, there have been many instances of lapses in checklist use, some with catastrophic results. If minimum standards for legibility, accessibility, and quick recognition were adopted, the availability of a checklist easy to read and use would discourage checklist misuse, whereas lack of standards in the past has contributed to this misuse. From that point it would become a question of airline training and discipline, and individual professionalism.

The material from the regional Part 121 carrier studied illustrated some of the shortcomings found in the manuals and checklists of smaller carriers, especially the Part 135 carriers, many of which fly airplanes produced outside the United States. Although the manuals and checklists of U.S. aircraft manufactured for the regional and Part 135 market don't generally come up to the standards of those produced by the U.S. manufacturers of large aircraft, the problems seem to be even worse in manuals and checklists for aircraft of foreign manufacture. Part of this is a problem of language and terminology. Part of it seems to arise from the fact that the manual and checklist material from foreign manufacturers is approved by their equivalent of the FAA under the bilateral agreement. Problems include:

- Lack of tabs in the manuals, which makes it more difficult to find important information quickly. One manual was tabbed but most of the tabbed sections were not numbered, even though references were made to those sections by number.

- Accessibility of important information. One AFM had no systems descriptions of any sort. Another, in its "Abnormal" and "Emergency" sections, frequently made references to figures and paragraphs in other parts of the manual rather than supplying the needed information at that point. These characteristics decrease the value of the manual as a reference in addressing abnormal and emergency situations.

- An excessive number of "Emergency" checklists, and a classification of "EMERGENCY" which was not consistent with general usage in the United States. The AFM for one foreign airplane contained 82 "Abnormal" and "Emergency" checklists, of which 39 were classified "Emergency." Many of the 39 would not have been classified "Emergency" by most U.S. standards.

- An excessive number of memory items. These checklists were for an airplane operated by a regional carrier, sometimes flown by low-experience-level crews. This combination of an overwhelming number of memory items and low-time crews is conducive to errors in emergencies.

- Missing items on checklists. Examples of this are seen in the following.

  - Carrier B

    No mention of "GEAR" on the "BEFORE STARTING" checklist, and no mention of "FLAPS" on any checklist prior to takeoff.

  - Carrier E

    On all three groups of checklists — "Normal," "Abnormal," and "Emergency" — there appear challenges without responses, as in "EXCESSIVE LOADMETER FAILURE," "BATTERY....." (no response).

  - Carrier G

    Operationally important items not carried over to the checklists from the AFM included:

    - From "ENGINE FIRE OR SEVERE DAMAGE," "FUEL CROSS-FEED.....SHUT."

    - From "ELECTRICAL SMOKE OR FIRE," "RECIRCFAN.....OFF."

- In some cases, "Emergency" checklists were not carried over from the AFM to the operating checklists. FAR 125.71 states that "Each certificate holder shall prepare and keep current a manual. A copy of the manual... shall be ...furnished to - (1) Its flight crewmembers." FAR 125.73 says "The manual must include...(m)procedures for ensuring compliance with emergency proced... es,..." FAR 25.1581 states "An Airplane Flight Manual must be furnished with each airplane, and it must contain the following: ...(1) Information required by 25.1583 through 25.1587." 25.1585,"Operating Procedures," includes emergency operation of the systems. One carrier was using checklists that did not include 11 "Emergency" checklists that were in the AFM. This certainly circumvents the intent of the FARs. Among the checklist procedures that were missing were the following:

- "ENGINE OVERSPEED"
- "PROP OVERSPEED"
- "FUSELAGE SMOKE OR FIRE"
- "DOUBLE GENERATOR FAILURE"
- "BATTERY OVERHEAT"

The "Emergency" checklists of another carrier also lacked many operationally significant procedures which were in the AFM. Among these were:

- "PROP MALFUNCTION — OVERSPEED"
- "FUSELAGE FIRE"
- "TOTAL ELECTRICAL FAILURE"
- "LOSS OF ALL SYSTEM FLUID"

Manufacturers as well as operators were remiss. An example can be shown from the AFM of one Part 135 aircraft. It lacks procedures or checklists to deal with problems such as "LOSS OF ALL GENERATORS."

- Procedures were not presented in the order in which they should be accomplished. One Part 135 carrier's "Normal" checklist had "SHUTDOWN" following "BEFORE TAKEOFF." Normally "SHUTDOWN" is the last of the "Normal" procedures. Procedures should be presented in chronological order.

- Internal inconsistencies were also found. These concerned a variety of issues such as:

  - Crew size. One operator's "Emergency" section preface contained the following statement:

    "Emergency procedures have been formulated based on single-pilot operation of the airplane."

    However, throughout the section of the Company Aircraft Operating Manual devoted to Flight Operations, there are many references to "Pilots" (plural) and "Crew Coordination." Although the aircraft can be flown single-pilot, it was obvious that the company intends it to be flown as a two- pilot operation at least part of the time. Yet, nowhere was it addressed how emergencies were to be handled during two-pilot operation.

  - Aircraft equipment. Another example of confusion in a Part 135 carrier AFM concerned the response to a warning light. The instructions were as follows: "Any illumination (or flicker) of either CHIP DETECT annunciator light (if installed) requires immediate shutdown of the affected engine."

    It is strange that an annunciator light so important that its illumination requires immediate shutdown of an engine could be placed on the list of options for an aircraft, and not be required equipment.

  - Procedures. Another carrier exhibited confusion between the AFM and the operational checklist. In the "AIR START — NO STARTER ASSIST" checklist, one item in the AFM called for "PROP LEVER..... ..FULL FORWARD." The same item in the checklist from the CAOM said "PROP LEVER... .....FEATHERED." Since the two are opposite actions, we wonder which is correct.

    If flight crews are to be expected to have confidence in and use checklists, the procedures that the lists describe must be correct and must be consistent with the procedures described in the associated manuals.

- A lack of clarity of purpose of the checklist and the AFM. An AFM is designed to present specific information to an operator's personnel, including flight crews, about the operations of the aircraft. It is not, nor is it intended to be, a training manual. This is also the case with a checklist, which is to be used to assure proper completion of items necessary for safe operation of the aircraft. Despite this, some operators use AFMs and checklists for conveying messages which should be given in training. Examples of this are illustrated from these instances in one carrier's checklists and another's AFM.

  - "Immediately prior to touchdown, lower up-wind wing and align the fuselage with the runway by use of the rudder."

  - "Piloting with an engine inop." - "Use

rudder and control wheel to control aircraft heading, maintaining aircraft wings essentially leveled."

- The "SYNPHR (synchrophaser) FAIL" checklist gives a procedure for eliminating the beat between the engines if the synchrophaser is inoperative.

Pilots at the career stage of flying for an airline should not need basic flying lessons. If they are not aware of the proper techniques by this time, training would seem a more appropriate means for correcting this than a checklist. Including training information in AFMs and checklists only increases their size and detail, and makes them more difficult to use for their intended purpose.

The format and content of a number of the regional carrier AFMs, Company Operating Manuals, and checklists that we reviewed indicated a need for standards and careful oversite concerning their design and publication. While some carriers provide their crews with manuals and checklists that are accurate and easy to use, others do not appear to recognize the importance of these documents to flight safety. One of the worst examples was seen in the "Emergency" checklist of one Part 135 Carrier. These had been stamped "FAA APPROVAL" and signed off by a POI (even though not required for a Part 135 operation) but lacked procedures for 11 "Emergencies" that were in the AFM. There were several carriers using checklists that were missing procedures that were specified in their AFMs; a number of these involving operationally significant items. Some of these omissions are in violation of FAR 135.83 (c). This may be symptomatic of the regional Part 121 and the Part 135 operators, and the surveillance given them. The interpretation of the FARs by POIs is sometimes inconsistent, and variable enforcement may result from this. This leads to practices in the use and design of manuals and to checklists which are questionable, and which at times detract from the safety standards intended to be provided by these documents.

3.3.7 Summary of Findings

- POLICY AND PROCEDURES FOR CHECKLIST USE

  All of the carriers had some direction for the use of checklists by their crews. The policies varied widely from carrier to carrier, though not necessarily differing according to the carrier's size. Some were very detailed policies, spelled out in operating manuals, covering all aspects of checklist use, and some were only notations in the margin of a checklist noting who was to respond to a challenged item.

  Several NTSB and ASRS reports identified poor crew coordination in the use of checklists as a likely contributor to aircraft accidents. The absence of detailed policies and procedures concerns the responsibilities of individual crewmembers in the use of checklists increases the possibility of poor crew coordination during safety-critical activities involving checklist use.

  Dual responses to checklist items were used by most Part 121 carriers, but by only one Part 135 operator. Many pilots consider multiple responses to checklist items to reduce safety. Checklists are frequently done on the roll. When the heads of both pilots go down, even for a moment, safety is compromised.

  The response "AS REQUIRED" was allowed by two of the six Part 121 carriers and six of the nine Part 135 carriers. Many required a specific response of a quantity or setting in place of "AS REQUIRED."

- ALPHANUMERICS

  The bodies of the checklists varied from clear, legible 10-point type, all caps, with good print quality, to six-point type, mixed case, difficult to read. In some cases, the type size used on "Emergency" lists was smaller than that used on the "Normals." Closely packed six-point type is difficult to read quickly under any conditions. It is easily misread under the stress of emergencies and/or under low cockpit illumination. The size and resources of the carrier had no apparent bearing on the legibility of the checklist: a major carrier had one of the most illegible checklists examined.

- CHECKLIST PRESENTATION

  Paper checklists were most commonly used for "Normal" checklists, although one carrier used laminated cards. Another carrier used a

mechanical checklist for "BEFORE TAKE-OFF" and "BEFORE LANDING," although they used paper checklists for all other "Normal" checklists.

With one exception, "Abnormal" and "Emergency" checklists were kept in manuals, many of which were not tabbed for quick reference. The carrier that was the exception used paper cards in color-coded folders kept in the cockpit.

- COLOR CODING

Only five of the carriers used any color coding, despite the fact that it could facilitate location of a critical checklist. Carriers cite cost as their reason for not using color coding.

- MEMORY ITEMS

Most carriers studied used memory items in "Emergency" checklists. One Part 121 carrier had reduced them to one item on each of three checklists, and one Part 135 operator had no memory items.

- CONTENTS AND ORGANIZATION OF MANUALS AND CHECKLISTS

Manuals and checklists for aircraft produced outside the United States often have problems with language, they lack tabs, there is insufficient detail, they contain too many modifications and changes, and have a classification of checklists different from what is normally found in the United States. In addition, operators report that changes are very difficult to get approved by the Administrator.

There were a number of instances of missing items on checklists, and groups of checklists not carried from the AFMs to the operating checklists.

Also, a number of things which could create confusion for the crews using them were noted. In some cases the order in which checklists were listed differed from the sequence in which the actions should be taken, thereby making them more difficult to use. Inconsistent policy statements on the handling of emergencies were seen. And there was one instance of opposing actions being prescribed by the AFM and the operating checklist on one "Abnormal" checklist item.

The manuals and checklists of the Part 121 carriers are generally better than those of the Part 135 carriers, but they could still be improved and standardized. There are, however, major Part 121 carriers that are worse in this respect than some Part 135 carriers, so it is not possible to judge quality only by the size and prominence of the carrier. AFMs for aircraft flown by regional carriers, whether produced by foreign manufacturers or in the U.S., were often not of the quality of content of those produced by the large U.S. manufacturers.

Frequently, there were large discrepancies between the content of the AFM and what was included in the Company Operating Manuals and checklists. Yet, there were instances where the abbreviated checklists, although lacking parts, were stamped "FAA APPROVAL" and signed off by a POI. This would seem to demand more cautious and knowledgeable surveillance.

3.4 ALPA SURVEY

3.4.1 Introduction

A survey of airline pilots was done by the Air Line Pilots Association (ALPA) to obtain opinions on the design and use of checklists from those who use them on a daily basis. Surveys were mailed by ALPA to the Central Air Safety Chairmen and Local Air Safety Chairmen of eight airlines, for distribution to "pilots in different crew positions and flying different aircraft, if possible." Survey questions ranged from the subject of pilots' use of checklists to the design of checklists. ALPA promised anonymity and requested a return within a one-month period. Eighty survey forms were sent out and returned. (A copy of the survey, including important results, is attached as Appendix D.)

3.4.2 Respondent Characteristics

- The number of types of transport aircraft flown ranged from 1 to over 10 per individual, with an average of 3.83 types.

- The average hours in each seat were:

Captain	4,140
First Officer	5,570
Second Officer	2,910
(22 had no S/O time)	

- The lowest hours in each seat were:

Captain	0
First Officer	3,000
Second Officer	2,000

- The highest hours in each seat were:

Captain	20,000
First Officer	10,000
Second Officer	5,000

- Age ranged from 31 to 66 (the oldest being a retread Captain returning as Second Officer) with an average age of 45.78 years.

- Forty-one percent wore corrective lenses to fly.

3.4.3 Checklist Layout, Design, and Use

- POLICY FOR CHECKLIST USE

  Ninety-three point six percent responded that their airlines spelled out a standardized method for the use of checklists. (This is considerably more than we found in our review of Parts 121 and 135 carriers.) Almost as many felt that the crews followed the prescribed method. However, when asked if the prescribed method could be improved upon, almost half said "Yes." Some of the pertinent suggestions included simplification, enforcement, and standardization.

  - "Simplified (checklists) to prevent 'crews not using prescribed method', and use enforced by all levels of administration and training."

  - "Responses from aircraft (type) to aircraft (type) should be the same."

    (One problem with this is that the manufacturers can't agree on what the name for an object is—i.e., "power lever"/"throttle," etc., and many checklist responses are tied to placards on cockpit panels or aircraft manual terminology.)

  - "Do not require dual response by the pilot flying the aircraft."

  - "On two-man crews, checklists are too long, especially final items before take-off. And I feel the F/O (First Officer) should read the challenge and respond while on the ground." (The respondent wants the F/O to be responsible for all aspects of the checklists on the ground, freeing the Captain for operational duties.)

- ALPHANUMERICS

  Thirty-nine percent felt it was easy, with current checklist typography and designs, to skip items unintentionally. Although 94.5% indicated that print size was adequate, when asked later in the survey if they felt that larger print would be an improvement, 75% said "Yes." The fact that 41% of those responding wear corrective lenses to fly may be pertinent here.

- METHOD OF PRESENTATION

  - LAMINATED CARDS

    Of those responding, 66% are currently using laminated cards, either for their "Normal" checklists or for all checklists. Of these, 20% use another form of checklist in addition (such as "Emergency" and "Abnormal" checklists kept in a manual). Eighty-eight felt that it was not advantageous to use a mix or combination of checklist types, such as paper and mechanical checklists.

  - ELECTRONIC CHECKLISTS

    The small number (six) of respondents using electronic checklists on CRTs felt the CRT was superior to the paper checklist except on "heads-down time" required. On that, three felt the CRT took more "heads-down time," two felt the paper checklist did, one declined to answer the question. They all felt that the CRT check-

lists were easier to use in all cockpit lighting conditions; that they were easier to get at; that they were easier to use in all operating conditions; that they facilitated quicker use; and, that if items were skipped, they could be more easily returned to than with a paper checklist.

The suggestion of using automated (electronic) checklists wherever possible met with a positive response. Fifty-eight point six percent of the respondents felt it would be helpful, but the following qualifications are typical:

"No matter how they are presented, automated or clay tablet, they must be read and followed."

(This indicates that at least one of the respondents is doubtful that reading and following checklists is done consistently and uniformly.)

"I don't like the idea of automated or mechanical lists because of the frequent changes to our checklists. The cost of changing these would make it harder to get the company to make changes."

- MECHANICAL MARKERS

The suggestion to "use a mechanical marker to mark checklist progress" met with little enthusiasm. Many felt it was an archaic concept. One said he already used one - "called a finger." However, in jumpseat observation rides we had the opportunity to watch a crew using a mechanical slide checklist for "BEFORE TAKEOFF" and "BEFORE LANDING." They were enthusiastic about it, felt that it provided a positive indication of checklist progress, and eliminated the problem of losing one's place in interrupted checklists.

- COLOR CODING

When asked if they felt "use of color coding for easy identification of checklists" was a good idea, 83.7% said "Yes." This is used by some airlines, both Part 121 and Part 135. Some of the comments elicited were:

- "Our current procedure."

- "For Emergency checklist at least."

3.4.4 Checklist Interruptions

Checklist interruptions come in two varieties:

- Interruptions to checklist use.

- Interruption of operational tasks by checklist use, such as can occur during a busy approach or an emergency.

While most of the respondents felt that interruptions were a problem, not everyone agreed. One sheltered soul said:

"Checklist procedures are not compromised by interruptions. I have never seen an error from an interruption."

He was, however, a definite minority of one, in that respect, as the following survey results regarding interruptions will show.

The respondents were questioned about the importance of potential interruptions to checklist use, and asked to rate them on a scale of 1 to 10, with 10 indicating very important. While a few scored some of those listed very high, the average scores were middle of the scale. The top-ranked four were as follows:

- ATC communications

"ATC should be educated/indoctrinated to the hazard(s) associated with multiple frequency changes (which takes attention from the checklists/lookout doctrine/navigating, etc.) during descent/approach (VFR and in the weather). This also removes the pilot not flying from the 'network' at a critical time. Frequency changing requires intense attention inside the cockpit..."

Others voiced similar sentiments:

"Most disruptive area of operation and checklist interruption: ATC transmission in initial approach area. Try and read a checklist between CIVET (52.4 miles NE of LAX) and LAX on a VFR day. Typical to have six frequency changes, a dozen

transmissions while 'setting-up' bugs and radios for two different approaches, and being assigned to side-step to land on a third runway. Usually flight crew cannot respond as controller goes from one transmission to another in steady stream of clearances and modifications to clearances."

- Ground personnel communications

  Respondents identified conversations with gate agents, fuelers, push-back crews, mechanics, etc., as disruptive of checklist operations prior to taxi.

- Flight attendant requests

  One respondent felt so strongly about this source of interruption that he scored it 11 on a scale of 1 to 10, and most felt that this was a problem in at least some phases of operation. There was no agreement on which phase was most affected. One respondent said:

  > "Interruptions are my big deal. F/As (flight attendants) who either don't know or don't care what you're doing, ATC, etc. How do you stop that?"

- External taxiing distractions

  This covered everything from complex airport layouts, to poorly marked taxi- and runways, to other airport traffic. A major contribution to this problem is ground vehicles which do not give way to aircraft, and over which ground controllers claim to have no authority.

  It has been suggested from time to time that taxiing distractions could be eliminated by stopping the aircraft until the checklist was complete. When queried about this, about 72% said "No." The following comments are typical:

  - "Very difficult to stop and run takeoff check at most airports."
  - "Not practical."
  - "Checklists can be distracting when taxiing, but can be managed safely."
  - "Pilots are capable of responding while taxiing."
  - "We can walk and chew gum."

The consensus seems to be that they can handle the distractions. However, ASRS and NTSB data indicate that distractions may be more disruptive than many pilots are willing to admit.

This last category, "External taxiing distractions," also contains elements of the second type of interruption — that of the checklist becoming an interruption to operational tasks.

Asked if they felt "there are times when the use of a checklist creates an interruption to good operating procedures?", 39% said "Yes." One felt that during an Abnormal/Emergency situation he should handle the problem and use the checklist when and if he had time. Another said the problem was worse during taxi out.

> "While checklist is being run it is easy to miss radio calls. It is better without so much dual response."

A report from the All Nippon Airways Flight Standards Committee quotes the 1979 NASA ASRS 9th Quarterly report, concerning checklists becoming an interruption to operational procedure. And an analysis from that 9th Quarterly report of ASRS air carrier distraction reports associated with checklists, found two characteristics common to all the reports.

1. "Every report indicated that checklist accomplishment received cockpit priority over ATC requirements. Every incident ended in a potential or actual violation of ATC rules or regulations."

2. "The checklist activity was almost always going on at the same time other cockpit tasks were being performed; radar monitoring, minor malfunctions, system operation, traffic watch, etc. Checklist accomplishment became a cause of distraction, not by itself but as a part of cockpit workload. In the incident(s) reported, the workload became 'excessive' and 'time ran out' before all tasks could be completed."

> Clearly, the use of checklists in the cockpit is required for safe operations. Just as clearly, they must be used in an environment that is disruptive and promotes error in their use. At the same time, checklist use is an important contributor to cockpit workload. Checklists that are easy to read and use will be more resistant to error and will contribute less to cockpit workload than those that are not.

3.4.5 Compliance, Crewmember Variations, and Cockpit Resource Management (CRM)

One issue that surfaced during the survey was that of crew compliance. One respondent commented:

> "Checklists are not that important. A bad crew can screw up a good checklist. A good crew can work safely with any checklist."

Other comments included were:

- "Checklists are mandatory for safety. However, they are only as good as the persons reading them."
- "Personal discipline seems to be the major variant."
- "Don't give into complacency - it's our biggest foe."

Though the overwhelming majority indicated that their airlines prescribed methods of checklist use and their crews adhered to them, 72.6% also felt that individual crewmembers influenced the manner in which checklists were performed. Sixty point five percent felt that this resulted in variations in checklist performance, and 43.6% felt that this meant checklists were done in a nonprescribed way, or were not done. There appears to be an inconsistency in these responses. Although stating that most crews followed prescribed procedure, they also felt that individuals had a great influence on the manner of checklist performance. The following comments shed light on the state of cockpit resource management and crew coordination:

- "This (the lack of standard use or nonuse) will be difficult to correct until the attitude of those individuals is changed."
- "Our captains are so nonstandard that the First Officer's job is much more difficult. Our airline provides us with basically good procedures and checklists, but the captains (particularly the older pilots) refuse to use them."
- "Some captains continually fail to call for checklists, leaving it up to the other crewmembers to be a little aggressive and ask if they're ready for it (the checklist)."

When asked if their airline had a policy of Cockpit Resource Management (CRM), 73% of the respondents indicated that their airline had a definite policy. The following comments are representative, although contradictory.

- "Most 'old heads' don't even understand the concepts in CRM, they are from the school of Zeus."
- "Our airline has a very good standard operating procedure. Even though the Captain has the ultimate authority, all crewmembers are encouraged to actively participate in cockpit operations and not hesitate to voice their concerns regarding irregularities or any sort of 'judgment' call."

These two respondents are apparently from different airlines, which espouse different philosophies on CRM. One appears to have a strong, definite policy which has been impressed on the crews, the other either no CRM policy, or policy which is not being followed.

3.4.6 Checklist Accessibility

When queried about the checklists they currently use, 31 (35.6% of those who answered the question) felt that their "Emergency" checklists were not easy to locate when needed.

- "I would have to dig into my flight bag for emergency checklist handbook."
- "Emergency checklists should be red for all fleets/airlines (color coding) and should be required by FAA to be readily accessible (emphasis added) - not in binders in flight bags."
- "BAe-146 needs a place to stow both 'Normal' & 'Emergency' checklists."
- "Abnormal/Emergency in manuals ... difficult to find."

- "I would like to see a card(s) with the immediate action emergency procedures with their none-memory [sic] reference actions in the cockpit, so we wouldn't have to be finding it in a book at a critical, busy moment."

3.4.7 Other Observations

Although almost 70% said that they had a personal "must check" list which they used in addition to the formal checklists, only about 1/2 felt this would be useful to all front-end crews. Whether this indicated that they felt this "must check" wouldn't work with others, or were reluctant to suggest imposing something else on other crews, was not clear.

A number used some form of memory jog to remind them to complete some items on a checklist (such as when taxiing with fewer than all engines operating). Examples of this are a coffee cup inverted over the flap handle, the checklist between the throttles, or a "post-it" note on the windshield. However, 62% said they just repeat the entire list. From the perspective of 21.5 years in airline cockpits, the writer finds this difficult to believe. We think 20% would be closer to the actual number.

When asked if their procedures were such that they found themselves reading checklists during periods of high workload, 62.5% said "Yes." The manner in which they coped with this is cause for alarm. While many said they stopped the checklist until they had more time, 30% said they "press on and hope that nothing gets missed." To again quote John Lauber in his Flight Safety Foundation address - "Another step involves the question of handling disruptions or distractions, some of which are not under the control of the crew, and others of which are. It must be recognized that any disruption or interruption of sequentially dependent tasks is associated with a high probability that some or all of the elements of these tasks may be missed entirely, especially if a significant amount of time passes during the period of interruption. Thus, operating procedures should explicitly state that any interruption to an ongoing sequence of activities, especially running checklists, will automatically trigger a restart of the process which was interrupted. Obviously, this has to be done in a reasonable manner, but it should be the dominant mode of operation for all pilots."

Responses to one survey question indicate that most crews follow the standard company procedures for checklist use. However, when asked later whether individual crewmembers influence the manner in which checklists are used, a majority of the respondents responded affirmatively. The following comment is a case in point:

> "Some two-man crews tend to abbreviate or use silent checklists during high workload times."

Our own cockpit experience reflects the fact that two-man crews tend to be less formal operationally than three-man crews, and the above comment supports this.

The suggestion of a core checklist with allowable variations for aircraft type and operating environment elicited mixed responses. The comments ranged from negative, to advisory, to positive. Some comments were:

- "A large group of pilots will never agree on anything."
- "An industry standard checklist will accommodate the lowest common denominator." (This ties in with an ASRS report received which cites a fleet with generic checklists. The writer complained of illogical flow patterns resulting from an attempt to accommodate different aircraft types, and of PA announcements on final approach.)
- "Would allow less confusion when moving to different aircraft."
- "This should be done with much input from line pilots. Not supervisory types and inspectors who do not have the experience. I've been in both situations."

The section requesting suggestions from the respondents to improve checklists elicited many comments. The following representative comments are quoted as received.

- "Keep them as brief and simple as possible."
- "State of the art - electronic checklists with throttle interlock (for critical items such as gear and flaps) for T/O (takeoff) and landing." (Four of the respondents suggested some version of this.)
- "Last items on pre-takeoff: killer items double-checked. Pan Am uses this." These would

include items which if not properly checked, could pose imminent danger to aircraft, crew, or passengers, as well as damage to persons or property on the ground during takeoff or landing. Examples of these would include fuel quantity and flaps on the "BEFORE TAKE-OFF" checklist and flaps and gear on the "BEFORE LANDING" checklist.

- "Checklists are like things-to-do lists. They're only helpful if you remember to look at them. Checklists get forgotten in entirety. If a keyboard response was required for each item on a 'BEFORE START' checklist before the engine start valve would open, that checklist could not be forgotten, etc."

- "We have to 'sell' the average line pilot that it is professional as well as 'cool/manly, etc.', to accomplish each checklist thoroughly every time! We have to show how it will help the flight crewmember himself to do the checklist."

- "In some fleets, skipping checklist items is routine because of the design of the checklist. That's where either the checklist or the procedure should be changed." (emphasis added)

- "My company management pilots need to more strongly endorse checklist importance and standardization."

- "Our airline has excellent checklists and procedures which are carefully followed by crews. Errors still creep in."

- "We must expect errors, and plan and design knowing there will be errors."

- "We don't need another gadget to check T/O warning systems. A specific 'Killer Item' recheck is appropriate."

- "Checklists must cover a dead tired crew."

- "Brevity and simplicity."

3.4.8 Summary of Findings

From this survey, we may draw some conclusions regarding checklists in everyday use.

- Larger print and/or better letter spacing on checklists would be desirable.

- The small sample of respondents who use CRTs for checklists find them preferable to other types of checklists. They all feel that the CRT checklists are easier to use over all cockpit lighting conditions; that they are easier to get at; that they are easier to use over all operating conditions; that they facilitate quicker use; and that if items are skipped, they can be returned to more easily than with a paper checklist.

  Our discussions with some corporate users of electronic checklists revealed a negative side to these devices. They indicate that CRT checklists can be more difficult to use; that they can require a great deal of heads-down time; and that it is cumbersome to return to skipped items.

- Pilots felt that the creation of a "core" checklist across industry lines would only meet the "lowest common denominator" and thus would penalize the innovators and the conscientious.

- Color-coding for easy recognition of checklists was reported to be desirable and is already being used by some operators. This takes different forms, from colored borders on checklist cards, to solid colored cards, to colored folders to hold the cards. Variations of all of these are being used by airlines at present.

- There are many sources of interruption to checklists. Some, such as multiple ATC communications at inappropriate times, are reported as causing distractions and increasing workloads.

- Most of the airlines which were covered in this survey were reported to have a policy for the use of checklists which the crews followed. However, 1/2 of the respondents stated that individuals in the cockpit influenced whether checklists were done correctly, or at all. This indicates a lack of compliance which should be addressed by the airlines.

- The survey questions concerning procedures for using checklists verify our concerns that, in fact, checklists are used in an environment that prevents crews from dedicating predictable chunks of their attention to the completion of these lists, and that they accomplish these lists under conditions that are ideal for causing

mistakes. Rather than dedicating chunks of time to checklist use, many crews perform these lists concurrently with other flight tasks. About 1/3 of those who responded that they found themselves doing checklists at times of otherwise heavy workload said that they continued with the checklist as they did other tasks, completing checklist items as they found time.

- Emergency checklists are often not easily located when needed. It was suggested that it be made mandatory for them to be carried in a readily accessible place in the cockpit, rather than within a manual in a flight bag.

3.5 OTHER SOURCES OF INFORMATION

3.5.1 NTSB and Related Meetings

We participated in discussions with an investigator for the NTSB and representatives of a regional Part 121 carrier who were developing a new checklist for a foreign manufactured aircraft that they had in service. The carrier's people expressed their concerns with the manuals and checklists that are available for use with the foreign manufactured aircraft that they are operating. We subsequently reviewed the AFMs and checklists for those aircraft.

One aircraft type had an AFM that covered the information required by the FARs; e.g., Limitations, Emergencies, and Performance (the greater part of the manual was devoted to performance). There was also a Normal section which encompassed "Normal" and "Abnormal" checklists. No systems descriptions were included. Other concerns and problems that this operator expressed included the following:

- One AFM contained 82 checklists for abnormal and emergency situations. Of the 82, 39 were "Emergency" checklists. Many of the 39, such as "UNPRESSURIZED FLIGHT," would not have been classified "Emergency" checklists by many U.S. manufacturers or airlines. However, the operators are constrained to use these checklists as they stand, with their multiple memory items, which put a heavy memory load on their sometimes low-experience-level crews. We quote from an Advisory Notice from the manufacturer pertaining to these checklists:

  "Operators are reminded that abbreviated checklists (as opposed to lengthy, detailed expanded checklists) are not published by _____ as a document approved by an Airworthiness Authority and, if they are to be used, they must comply at all times with current procedures as set forth in the latest revision of the Approved Flight Manual."

  FAR 125.75 states that "...the certificate holder may revise...if the revised operating procedures and modified performance data presentation are approved by the Administrator." This regional operator told us, however, that they had little luck trying to modify these manuals and checklists. Whether due to poor operator modifications or reluctance on the part of the POI to allow change, we don't know.

- This aircraft, since its manufacture (4+ years), has had an average of 300 modifications per year. Some of these modifications involve major hardware changes or procedural changes that necessitate checklist changes. Because of the volume of changes, the operator has found it difficult to modify the aircraft, keep their crews adequately informed, and make timely changes to manuals and checklists which then must undergo POI approval.

3.5.2 Air Transport Association (ATA) Flight Crew Checklist Working Group Meetings

The ATA hosted a working group on checklist and manual design to work with the FAA in developing guidelines for use by POIs in evaluating Part 121 and Part 135 manuals and checklists. This group was assembled to provide the FAA with industry input for the checklist and manual section of the *Draft Inspectors' Handbook*. We were invited to participate.

Prior to the two meetings that we attended, we met with the FAA member responsible for writing this section of the Handbook. We provided him with data we had found on recent MIL SPECS which provided guidance in manual and checklist construction (MIL-M-7700C, 18 May 1989, MIL-C-81222C [AS], 22 Feb. 1978, MIL-C-27278B, 5 July 1973). In addition, we advised him of checklist and manual problems that we had encountered in meetings and discussions with airlines. He, in turn, provided us with the results of the first Flight Crew Checklist Working Group meeting, which we had missed. This included the progress to date on the

writing of the Handbook. Also included was written input he had solicited from the airline representatives regarding their positions on manuals and checklists, and input for possible use in the Handbook.

Since this section of the *Draft Inspectors' Handbook* was something which would govern their manuals and checklists for the foreseeable future, the airlines participated actively. Their views were understandably quite parochial, and included much debate on semantics, to eliminate, as far as possible, any but very narrow interpretations by POIs. There was general agreement among the airlines that if it were not necessary to mention a specific point in the handbook, it should be left out completely, rather than having a general statement subject to varying interpretations.

3.5.3 Jumpseat Observation Rides

We took jumpseat observation rides on seven occasions, on four different airlines. We did this to see how checklists were actually being used in flight. The aircraft flown included two DC-9s, a MD-80, a DC-10, a L-1011, a B-727, and a Saab-340. None of the aircraft used a computerized checklist on a CRT. All used paper "Normal" checklist cards in varying sizes. On three aircraft, a mechanical checklist was used for the "BEFORE TAKEOFF" and "BEFORE LANDING" checklists. The crews using these mechanical checklists were highly in favor of them.

The manner in which the checklists were performed varied widely. Three crews from the same airline performed in a uniform manner, indicating thorough, standardized training. Two crews of another airline performed in a loose manner — sufficiently loose that one of them never ran the "BEFORE LANDING" checklist.

It appeared, from these jumpseat rides, that the performance of checklists in an airline that has a strong emphasis on training and standardization will be more likely to be uniform. Where less emphasis is placed on those factors, and less discipline prevails, checklist use will be correspondingly more variable.

3.5.4 Corporate On-Site Visits

Corporate aviation often makes use of the latest technology before the airlines, since corporations are not subject to the economic constraints imposed by a large fleet. They also frequently carry executives whose loss to the company in an accident could be critical. We believe this colors their thinking regarding technology vs. cost decisions. Interested in this tendency to use the newest equipment, we made on-site visits to two corporate aviation departments to assess their current checklist technology. A peculiarity of corporate aviation departments is that they can change their checklists whenever they want, as they see fit, and without prior approval, since they operate under Part 91.

One corporation flew two Canadairs and one Westwind. All three aircraft, at the time of our visit, used a backlit, fold down, scroll checklist for all "Normal" checklists. This was mounted in the center of the glare shield. The pilots reported that they liked it, as they always knew where they were in the checklists, regardless of interruptions. "Emergency" and "Abnormal" checklists were carried in the cockpit, in a laminated, color-coded, well-tabbed booklet prepared by Flight Safety Canada, Inc. This booklet also contained backup "Normal" checklists for use if the scroll was inoperative. These "Normal" checklists were not as comprehensive as the corporation's own, used on the scroll. All three aircraft have the capability of upgrading to automated checklists on CRTs, and the corporation stated their intent to do this in the near future. Since the checklists would usurp the radar presentation, in bad weather the crew would revert to the scrolls.

The other corporation had a larger aviation department encompassing a Gulfstream G-4, a Westwind 1 and 2, a Beech King Air, and a number of Bell Jet Ranger and Bell 222 helicopters. The fixed wing aircraft all require two pilots. The only case where a rotary wing aircraft requires two pilots is the 222 in IFR weather.

All their aircraft used laminated card checklists, despite the fact that the Westwind 2 had checklists available on the radar CRT. The reason given by the chief pilot was standardization. He also felt that the CRT checklists were more cumbersome to use, and took more time.

The G-4 will have the automated checklists installed in its Sperry, all-glass cockpit this year. It will have a dedicated CRT. Whether that installation will supplant the laminated cards remains to be seen.

The rotary wing aircraft crews did not use available checklists when underway. The only check normally done when underway is an engine gauge check on descent. During an engine loss or tail rotor failure, the crew is too busy to read a checklist. We

were told that they deal with "Abnormal" procedures instinctively, from an ingrained habit, and then refer to the Operations Manual kept in the aircraft. Checklists are also not used in two pilot IFR flights, where each pilot knows the Standard Operating Procedure and follows it when underway.
Although we anticipated that we might find examples of the latest technology in checklists in these visits, we did not. As noted above there was some interest in automated checklists on CRTs, but for the most part more conventional types were the standard.

3.5.5 Cockpit Devices in Use

In order to determine whether there was some new technology available which could be easily adapted to general use, and could help to eliminate checklist errors, we did a small survey of what was available. From the results of this survey, we have listed advantages and disadvantages of the various kinds surveyed (see Appendix B).

The automated checklist on a CRT is liked by many of those who use it. Some who use it on a regular basis and report favorably on it also report that it can take more heads-down time if anything unplanned or out of the ordinary occurs. Others report it as too cumbersome and use paper or laminated checklists instead, even when the other technology is available. In some cases, it usurps the radar CRT. Many aircraft would require a very costly retrofit to enable the use of this technology.

The checklist on a scroll has been around for many years, and is still used enthusiastically by many, including crews of some Air Force planes in the current inventory. It can be cumbersome to use if one needs to return to a prior portion of the checklist. It also takes up cockpit space, which is in short supply in many aircraft. In addition, it needs a paper checklist backup in case of mechanical failure. One corporation we visited used scroll checklists that were generated on a personal computer with a dot matrix printer — not the best combination for legibility. Their checklists did not require approval from a POI since corporations operate under Part 91, and this allowed them to make changes as they saw fit. Their preflight checklist contained 129 items, and other checklists also seemed excessively long.

By far the most prevalent types of checklists are paper or laminated paper. They come in various sizes and shapes, some big and unwieldy, some so small as to be unreadable except in perfect conditions. One major problem with these is the ease with which you can lose your place through interruptions.

We observed that mechanical checklists are used for "BEFORE TAKEOFF" and "BEFORE LANDING." Their users like them since they are a positive measure of checklist progress. The other "Normal" checklists that the crews use are paper or laminated cards.

We have seen one example of a unit which reads the checklists to the user in a synthesized voice. It will restate missed items until they are complete, if programmed to do so. As far as we know, it is currently only in limited use, with some corporate Part 91 operators. One major airline is considering doing an evaluation of this technology with an eye to possible use. One drawback that we can foresee is the addition of another noise in cockpits which are already noisy enough.

Some users kept all checklists in booklets in the cockpit. Some checklists were partially laminated throughout, some were in plastic sleeves. Those that were well tabbed and indexed were easy to use. One of the best examples of these was the checklist booklet from Flight Safety Canada, Inc., for use in the Canadair Challenger 601. This included color-coded, laminated tabs, well-indexed "Abnormal" and "Emergency" sections, and heavy, hard-finished paper pages with 10-point type or larger. It was easy to use and very legible. Moreover, the aircraft for which it was designed had a convenient storage slot for it; its compactness would make it easy to adapt other aircraft to accommodate it.

The worst example we saw was that of the checklist booklet from the Horizon DHC-8 involved in an accident at the Seattle-Tacoma International Airport, on 4/15/88. It was printed in eight-point type, mixed case (sometimes all lowercase), and not good quality of print. The tabbing can best be explained by quoting from the NTSB "Human Performance Investigator's Factual Report" of the accident:

> "Locating a specific checklist requires the user to identify the desired checklist in the table of contents, note the number of the divider at which the checklist is filed, and turn to the desired checklist which is inserted before (forward of) the numbered divider."

In a drill, at an informal meeting with the NTSB, a DHC-8 Captain was asked to locate the "ENGINE FIRE" checklist in the Horizon booklet. He was unable to do so in a reasonable amount of time. This inability to locate critical checklists is perhaps one reason why the "ENGINE FIRE" checklist was never completed in the Horizon accident.

3.5.6 Summary of Findings

Apart from paper and laminated card, no checklist devices were found which were easily adaptable to all aircraft types. And, one respondent to the ALPA survey commented that the aircraft he flew didn't even have a place to stow them.

As far as we can see, no manual device currently in use has the potential, by itself, to entirely eliminate pilot error in the use of checklists.

4. SUMMARY AND RECOMMENDATIONS

This includes a summary of the data gathered and recommendations for improving checklists.

4.1 FINDINGS

4.1.1 Conformance

Twenty of 21 NTSB reports illustrate that lack of conformance with standard operating procedures may be as big a problem as checklist layout and design, if not bigger. Forty-three percent of the ASRS reports indicate that a lack of training contributed to this lack of conformance. Comments by ALPA support this indication. We observed an instance of this during one of our jumpseat rides where the crew did not read their "BEFORE LANDING" checklist.

The inconsistent application of policies and procedures for checklist use may also adversely affect conformity. Some operators were very specific in the guidance they gave their crews, others gave no direction on either policy or procedures for checklist use. The latter were frequently vague as to who challenges, who responds, and when.

4.1.2 Interruptions

Fifty-eight percent of the ASRS reports mentioned interruptions as being the cause of problems in checklist use. The interruptions fall into two categories:

- External interruptions to the crew during their use of a checklist.
- Interruptions to operational tasks caused by using a checklist.

The ALPA survey confirmed the disrupted and disrupting aspects of checklist use and its implications for flight safety.
We also observed that operations activities often led to checklists being done from memory; responses being given without the corresponding action being taken, and checklist items being missed. Similarly, our cockpit observations revealed that diligent use of checklists by flight crews while taxiing could easily detract from the safe operation of the aircraft on the ground.

4.1.3 Checklist and Manual Design, Organization, and Contents

Missing, inconsistent, and incorrect procedures were said to contribute to 20% of the problems in the ASRS reports. In fact, we found many of these problems in our review of Part 121 and Part 135 operators' manuals and checklists. And many of these manuals and checklists also lacked organization and the completeness needed to support informed use by flight crews. The manuals and checklists provided by large U.S. manufacturers were usually more organized and easier to use than those from foreign or small U.S. manufacturers. The lack of organization and clarity in the manuals and checklists from the smaller and foreign manufacturers often presented a problem for regional carriers flying the smaller, commuter-type aircraft. However, even the manuals and checklists from large U.S. manufacturers suffered at times from changes made by the operators. This resulted in an end product that was no better, and occasionally worse, than what was available to small carrier crews.

Examples of the problem found included the following:

- checklist procedures not in the order in which they should be used;
- items missing from checklists and/or not carried over from the AFM;
- procedures specified in the Airplane Flight Manuals (AFMs) inconsistent with actions prescribed in the operating checklists;

- whole sets of procedures not carried over from the AFM to the operating checklists;

- incomplete procedures;

- checklists difficult to locate in manuals either because of poor tabbing, poor indexing, or poor titles.

4.1.4 Readability

The typography of manuals and checklists varied widely, from five-point type to 10-point type or larger, the smaller type being difficult to read. Often print was blurred, and contrast of print to background poor, despite the obvious fact that if manuals and checklists are difficult to read, they will be difficult to use. The *Air Carrier Operations Bulletin Part 135 No. 88-5 - Flight Crew Checklists (NTSB Safety Recommendation A-88-72.)* says:

a. "The National Transportation Safety Board (NTSB) in their investigation of a commuter air carrier accident discovered that the flight crew checklist was not constructed in such a manner that would provide adequate legibility in normal or emergency conditions. NTSB believes that under operational circumstances, a deficiency in legibility and size of print could compromise the intended use of this device.

b. Principal operations inspectors should take appropriate actions during the course of routine air carrier surveillance, inspections, or flight checks of their assigned operators for review of current checklist format. Flight crew checklists used by air carriers should include the appropriate actions necessary for normal and emergency procedures, printed in clear, concise, and legible form."

Though directed at Part 135 operators, this applies to all operators. The regulations should be changed to reflect the same standards for Parts 121 and 135 operators. The current regulations reflect a lack of clear and consistent direction for manufacturers, operators, and POIs alike. The manufacturers should have clear guidelines to follow in producing usable manuals and checklists for new aircraft. The operators should have clear manuals and checklists for their crews. And the POIs and evaluation groups should be given unambiguous guidance on what standards to apply to the design of manuals and checklists.

4.1.5 Color Coding

Color coding of checklists and manuals is used very little, although it could facilitate location of a critical checklist. The airlines usually cite cost as the reason for not using color coding.

4.1.6 Inconsistency

Often there was a lack of consistency between AFMs and checklists. In some cases, checklist items and even some procedures were not carried over from the AFMs to the operating checklists.

4.1.7 Definition of "Abnormal" and "Emergency"

The use of the terms "ABNORMAL" and "EMERGENCY" were inconsistent among manufacturers and operators and from aircraft type to aircraft type within the same operator's fleet. The use of "NORMAL," "ABNORMAL," and "EMERGENCY" is sometimes inconsistent throughout a fleet. The terms themselves vary, with the terms "NON NORMAL" and "IRREGULAR" used somewhat interchangeably with ABNORMAL" and "EMERGENCY," but there are also differences in meaning.

The lack of a standard definition for "emergency" has created particular problems for checklist design. Excessive numbers of emergencies result in emergency checklists of extreme length, excessive numbers of memory items, and inconsistent responses to real emergencies that are not always so labeled, e.g., loss of all generators. One foreign aircraft that had 39 sets of "Emergency" procedures, many of which would have been classified "Abnormal" by major U.S. manufacturers. Inflight events that are classified as emergencies (for example, low-level unpressurized flight) in one aircraft type but not another in the same fleet reduces the flight crews' respect for the term and contributes to their confusion regarding their priorities for action.

4.1.8 Emergency Checklists

"Emergency" checklists are sometimes difficult to locate when needed. They are often in manuals stowed in flight bags and are reported to be difficult to retrieve.

In some cases in our study, we encountered groups of "Emergency" checklists that had an excessive number of checklists (39 in one case). This made the checklists cumbersome to use and made it more difficult to find a single checklist.

4.1.9 Heads-Down Time

The use of CRT-presented rather than hand-held

checklists may be expected to increase flight crew heads-down time. This, coupled with the amount of heads-down time necessary for reprogramming computers when changes of routing are received, could cause important decreases in the capability of the crew to concentrate on other duties such as monitoring traffic.

4.1.10 Summary of Factors Detracting from Good Checklist Design and Use

Flight deck observations, pilot reports, relevant aviation safety databases, and our review of checklists and handbooks currently in use by some air carriers indicate:

- Operational conditions and priorities limit the time available to flight crews for examining checklist items.
- Use of checklists involves flight crew heads-down time that can be dangerous during terminal operations.
- Some flight crews only use checklists when it does not slow down other aircraft operations.
- Regardless of time available, some crews do not use checklists during some operations for which lists are provided.
- The print on some checklists is difficult to read under poor lighting.
- Responsibility of individual crewmembers concerning checklist use is not always clear or well defined.
- The types of items included on checklists vary among carriers.
- Some inflight events are considered emergencies by some carriers but not by others.
- Emergency checklists and handbooks are not always quickly accessible to the flight crew.
- It is difficult to quickly locate emergency procedures in some checklists and handbooks.
- Procedures indicated on some checklists are inconsistent with those described in the companion flight manual.
- Some checklists do not include procedures for all common emergencies.
- In some cases, the size and formatting of emergency checklists makes them more difficult to read than normal checklists.

4.2 RECOMMENDATIONS

We did not collect sufficient data to determine if poor checklist design and poor habits in the use of checklists were widespread throughout the industry. However, our data do support the conclusion that there are Parts 135 and 121 carriers who are operating with poorly designed checklists and manuals, and who have flight crews who are not well trained in the use of these aids and who admit to not using them when they are expected to.

Accordingly, we make the following recommendations regarding the design and use of checklist and manuals. We also recommend supporting research and development activities.

4.2.1 Checklists

- "Normal" Checklists should be short and easy to use. They:
  - Should include only those items that are pertinent to the safety and control of the aircraft.
  - Should be listed in an order that minimizes heads-down time and the attention of more than one crewmember at a time.
  - Sublists, e.g., "BEFORE TAXI" checklist and "AFTER TAKEOFF" checklist, should appear on the checklist card in the order in which they will be used.
  - Should have selected safety critical items such as gear and flaps as final items on "BEFORE TAKEOFF" and "BEFORE LANDING" checklists, even if this repeats an earlier item in the checklist. This will facilitate quick and last-minute reference to these items.
  - Should have alphanumerics of sufficient size, clarity of print, and contrast, to be easily read under any illumination conditions likely to be encountered in the cock-

pit. In the absence of cockpit research dealing specifically with this issue, we recommend, in "Guidelines" (Appendix A) that the checklist body be 10-point type, boldface, all caps, and that the checklist title be 12-point type, boldface, all caps.

- To the greatest degree possible, should have no greater number of items than can be presented on a single checklist card and can be easily read and stowed in a readily accessible place in the cockpit.

- "Emergency" checklists should be quick to access and easy to use under stressful conditions. They:

  - Should be quickly accessible in the cockpit by both the Captain and First Officer.

  - Should be available on a card (on the reverse of the "Normal" checklist card if possible) as well as in the manual.

  - Should be in a standard format. The order in which the emergencies are presented on the card should be standardized. This should cover all aircraft types in a company's fleet, and should take a form such as all engine problems first, or all fires first, etc., (to be decided by each company). In this manner, a crew flying for a particular company will know where to look for individual checklists regardless of what aircraft they are flying. In addition, the order in which the procedures are presented for each emergency should be standardized to the greatest degree practical, particularly within type.

  - Should have a clearly defined start and finish with a title set off by type two sizes larger than that of the text, boldfaced, and all caps. Each list of procedures should be clearly separated from other lists. This should facilitate quick identification under conditions of stress and low illumination.

  - Should be composed of type no smaller than that of well-designed "Normal" checklists, and if space permits, larger. "Emergency" checklists are often used under circumstances of environmental and psychological stress, and consequently should be as readable as possible.

  - Should be easy to understand and execute. Each "Emergency" checklist should be composed of only those items needed to combat the emergency. They should be listed in the order in which they are to be performed. They should be stated in common terminology, in a positive manner, and in as few words as can be used to convey the action.

    Subsequent procedures which must be performed as a result of the emergency procedure, (e.g., "SINGLE GENERATOR" procedure after a generator loss due to shutting down an engine as a result of an engine fire), should be covered in the expanded checklists in the manual.

4.2.2 Manuals

- Procedures for checklist use:

  - Should be clearly defined in the manual. This should include clear direction as to which flight officer reads what challenges and which responds, and should specify this for each phase of operation; i.e., airplane stationary, airplane taxiing, airplane in the air.

  - Should require quantitative or differentiating responses for all appropriate checklist challenges. Whenever possible, responses should specify position or quantity; e.g., FLAPS....20, FUEL.....48,000#, etc. The answer "AS REQUIRED" should not be allowed.

  - Should limit dual response items to the highest priority safety critical items.

  - Should require that checklists worn to the point of reduced readability be immediately replaced. No Minimum Equipment List (MEL) delay should be allowed on this item.

- Format requirements:

  - Should specify a standardized table of

contents, including clear reference to the checklist sections.

- Should include tabbed dividers for sections that may have to be accessed quickly. For checklists, these should include standardized, color-coded tabs, by section ("Normal," "Abnormal," and "Emergency") and appropriately labeled tabs within each section. Each section should begin after the tab with the first page being a clear, alphabetized index.

4.2.3 Checklist Training

The required training curriculum for each airline should incorporate checklist training, including:

- Proper use of checklists.
- Crew coordination in the use of checklists.
- The necessity for compliance with checklists.

4.2.4 Review of FARs

This review should be conducted to determine the need for:

- A clear definition of "NORMAL," "ABNORMAL," and "EMERGENCY." If not accomplished by FAR change, this should be specified in an Advisory Circular. This will standardize the use of these terms for both manufacturers and airlines, and should provide the means to design "Emergency" checklists which are similar in length and content. At present, some manufacturers include in their "Emergency" checklists many checklists that would be considered "Abnormal" by others. This has resulted in some "Emergency" checklists of excessive length.
- A rewrite of the FARs, or an Advisory Circular, to indicate that manuals and checklists for Part 121 and Part 135 operators have essentially the same, well-defined basic requirements. This should include all stages from initial approval to operator requested changes. Those parts not required by the scope of operation of smaller Part 135 carriers could be eliminated.

4.2.5 Research and Development

Research and development should be conducted to:

- Establish quantitative and behavioral criteria for checklist accessibility and readability.
- Develop a prototype checklist for use by safety inspectors for evaluating air carrier checklists and flight manuals.
- Develop and evaluate the usefulness of a standard format organization, and table of contents for aircraft flight manuals.
- Evaluate the use of all caps vs. mixed case lettering in checklist design.
- Develop and evaluate the use of a standard terminology for controls, displays, and inflight operations in checklists and flight manuals.
- Evaluate the utility, safety benefits, and limits of audio checklists, checklists on CRTs, and checklists with artificial intelligence features, both in a laboratory setting and in an operational context. (There is currently an audio checklist design available from Heads-Up Technology that will be the subject of a study by a major airline.)
- Evaluate the benefits of color coding and different font styles on checklist readability for electronic as well as paper checklists.
- Evaluate the operational feasibility of safety critical checklist item interlocks that would prevent aircraft takeoff without completion of safety critical items.
- Evaluate the utility, safety benefits, and limits of mechanical checklists such as those used by a major airline for "BEFORE TAKEOFF" and "BEFORE LANDING."
- Develop and evaluate a prototype checklist for Parts 135 and 121 use. This list would be developed as an example of how human factors principles in the use of formatting, font size, and color coding can be applied to checklist design.
- Determine the influence of memory items on emergency checklists on the speed and accuracy with which emergency procedures are performed.

APPENDIX A

Checklist Guidelines

CHECKLIST GUIDELINES

The need for a set of standards to guide manufacturers and airlines in developing manuals and checklists is becoming more and more apparent. Any proposed guidelines would have to encompass a number of areas, such as print size and style, format, color coding, overall color use, brevity, clarity, etc. Another area of concern is readability under all conditions of cockpit lighting, from bright sunlight cruising at altitude to night flight with low ambient cockpit lighting. Although supplementary lighting would normally be used in the latter case, too much white light will temporarily destroy night vision.

Bearing these points in mind, the following set of guidelines are proposed as the first step in the final development of a set of standards for industry use.

PRINT SIZE AND STYLE

Figure A-1 shows two extremes of print size and style. The first is a copy of the actual checklist on a Jetstream 31 involved in an accident in New Orleans in 1987. It is representative of the size and style of print used in the checklists of some smaller carriers and is clearly too small (0.075") and tightly spaced for adequate legibility under the range of lighting conditions which an aircrew will normally encounter. Figure A-2 is a copy of the actual checklist on an MD-80 that was involved in an accident in Detroit in 1987. The print is the same size as that of the Jetstream 31 checklist, and although it is formatted better, we still find it too small for easy readability in all lighting conditions. The second example in Figure A-1 demonstrates the recommendation made in the *Human Engineering Guide to Equipment Design*, for use if any lighting conditions less than one-foot candle can be expected. Although highly legible, the letters are too large (0.20") for practical use.

What we recommend is between the extremes cited above and finds its basis in MIL SPEC recommendations and current applications by a number of major airlines. An example is shown in the DC-9 checklist in Figure A-3. In that example, the print size is 0.15" (14 point) for the primary heading (DC-9 NORMAL...); 0.125" (12 point) for the checklist names (i.e., BEFORE STARTING ENGINES); and 0.1" (10 point) for the checklist text. It is also done in all caps, boldface type, with the exception of the notes, which are in initial caps with lowercase following. MIL-C-81222C and MIL-C-38778A specify the use of 14-point (0.15") type for checklist headings, and the use of 12-point (0.125") type for the body of the checklist. Both of these are slightly larger than that used in the DC-9 checklist and appear to represent a good compromise between legibility and practicality.

From the practical standpoint, the use of 12-point type (0.125") throughout the text of a document results in 54 lines of type, with 1" margins top and bottom, on an 8 1/2" x 11" page (i.e., the size used in this report). The size shown in example two of Figure 1 (0.2") results in 29 lines on an 8 1/2" x 11" page with less than 1" margins top and bottom. Since many checklists contain more than 29 items, this would result in an increase in the number of pages required to accomplish a checklist. We feel that normal checklists should be kept to no more than one 8 1/2" x 11" page — either laminated or trifold — if a card checklist is to be used. The reasons for that are as follows:

a. Many pilots clip the checklists to the yoke or parts of the window apparatus for use. This is easy with one page — more than one page becomes too bulky.

b. Having to flip through more than one page to read normal checklists in a multiple-leg day is cumbersome.

c. A checklist of one page can be found more easily and quickly.

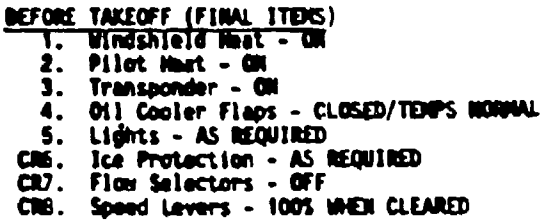
d. A single-page checklist is easier to stow and retrieve when needed.

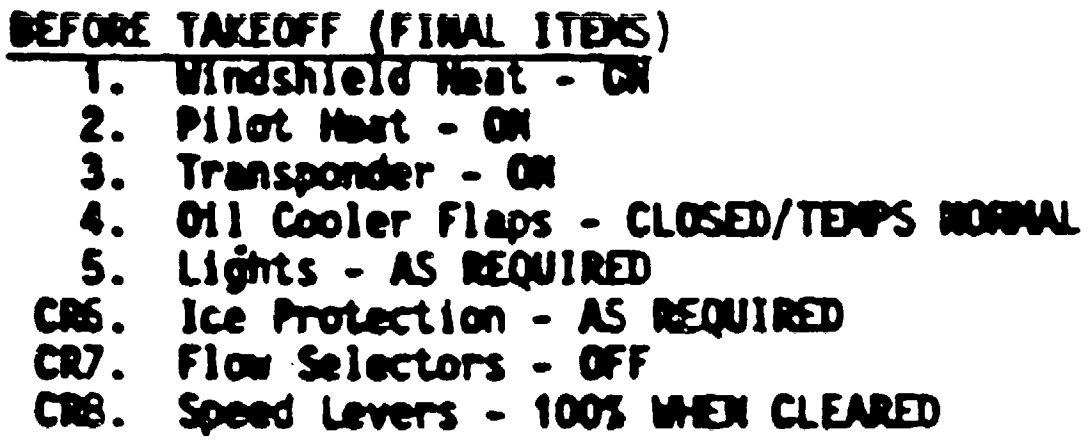
e. We feel that anything that promotes ease of use with a checklist will discourage misuse, or neglect, of checklists.

Based on the above, our recommendations for print size and style are as follows:

1. CHECKLIST HEADINGS — 12-point (0.125") type, all caps, boldface, in a typeface equivalent to those recommended in the MIL SPECS. These should be black type on a white background, or white lettering on a dark background. The latter is recommended in MIL-C-1472C, in "Human Engineering Guide to Equipment Design," and is currently in use by Flight Safety Canada, Ltd. in their Canadair checklists. Flight Safety varies the background according to the type of checklist: white for

FIGURE A-1. EXTREMES OF PRINT SIZE AND STYLE





normal, yellow for abnormal, and red for emergency. In the interests of economy, the users may wish to stay with black lettering on a white background, however, the white on a dark background we have found to be easily read under all light conditions and we recommend it.

2. CHECKLIST TEXT — 10-point (0.1") type, all caps, boldface, in a typeface equivalent to those recommended in the MIL SPECS. This should be black lettering on a white background.

3. NOTES — 10-point (0.1") type, initial caps, lowercase following, in a typeface equivalent to those recommended in the MIL SPECS. This should be black lettering on a white background.

If space and economy permit, we recommend moving up to 14-point type (0.15") for checklist headings and 12- point type (0.125") for checklist text and notes. Flight Safety has done this in their Canadair checklists and it produces superior readability.

FORMAT

We recommend a format of challenge and response —consisting of the query to the left margin, followed by a dotted separation, followed by the required response (to be right justified). This is the specified format in MIL-C-81222C, is quite common in industry use, and is illustrated in Figures A-2 and A-3.

COLOR CODING

Throughout the industry the use of color-coded annunciator lights is standard — red indicates "WARNING" or danger, yellow indicates "CAUTION," green indicates safety. Flight Safety Canada, Ltd. and some air carriers have carried this color coding through in checklist use. "Abnormal" checklists are identified by headings of yellow, and "Emergency" checklists by headings of red, with the "IMMEDIATE ACTION" items boxed in red.

We recognize that to do this is more costly, but we recommend it strongly. Color coding such as the above lends itself to ready identification, and hence ease of use.

OVERALL COLOR USE

The MIL SPECS previously quoted specify the use of black type on white paper, with the exception of the checklist headings recommended to be white print on a dark background. However, a limited study done by the head of the Publication Department of a regional carrier, in conjunction with an optometrist, indicates that better readability is attained under normal variations of ambient cockpit lighting by the use of black type on a bright lemon yellow background. This would appear to be borne out somewhat by the study done a number of years ago by big city fire departments which led to new equipment being delivered with bright yellow paint. They found that the equipment was more visible to other drivers with that paint scheme than with the standard fire-engine red. Once again, economics entered the picture, and most fire equipment is still red.

We have seen the results of the regional carrier study and agree that it promotes better readability under a variety of ambient cockpit lighting conditions.

BREVITY AND CLARITY

The following is a quote from MIL-C-81222C: "...procedures shall be presented in checklist form, abbreviated from the amplified checklist or procedures in the NATOPS Flight Manual. This abbreviation is to be accomplished by omitting explanatory material and reducing the check item to the minimum necessary to describe the required action. For example, the step 'Reduce airspeed to 130 knots IAS for best glide' can be abbreviated 'Airspeed - 130 KIAS Glide'." MIL-C-27278B says: "The procedures of the checklist shall be derived by abbreviating the procedures and eliminating the amplifications of the procedures in the procedure sections of the parent manual..."

As indicated by the above, no ambiguity or excess verbiage should be allowed in checklists. The required items and no more should be covered. One checklist studied had 139 items on the "AIRPLANE ACCEPTANCE" checklist. This is excessive. These items should be checked on a defined preflight, but to cover every item on a preflight in a checklist is to court checklist neglect by crews.

LEXICON

Standardized terminology, consisting of common aeronautical terms, should be used in all cases. MIL-M-7700C says: "Standard terminology. In most cases, use the terminology for equipment that is consistent with the intended operator's standard usage and is preferable to some of the more technically descriptive nomenclature [sic]. Some examples are: `throttle' vs. `power control lever', `circuit breaker' vs. `fault circuit detector'..."

FIGURE A-2. MD-80 CHECKLIST

MD-80

EXTERNAL ELECTRIC & PNEUMATIC SOURCE - START

PNEUMATIC X-FEEDS ..... BOTH CLOSED
PNEUMATIC AIR SOURCE ..... CONNECTED & ON
PNEUMATIC X-FEEDS ..... OPEN
PNEUMATIC PRESSURE (25 PSI MIN) ..... CKD
COMPLETE - BEFORE START CHECKLIST

AFTER ENGINES STABILIZED

PNEUMATIC X-FEEDS ..... BOTH CLOSED
ELECTRIC POWER ..... *CKD
EXTERNAL ELECTRIC & PNEUMATIC ... DISCONNECTED
COMPLETE - AFTER START CHECKLIST

BEFORE START

BRAKES ..... SET
WINDSHIELD HEAT ..... *ON
FUEL PUMPS ..... *(AS REQ)
CABIN PRESSURE CONTROLLER ..... *SET
AUX HYDRAULIC PUMP & PRESSURE ..... *ON & CKD
CIRCUIT BREAKERS ..... **CKD
AUTOLAND ..... CKD
RADIOS, ALTIMETERS & FLIGHT DIR .... **CKD & SET
FUEL & OIL ..... **(QUANTITIES) & RESET

IGNITION ..... ON
SEAT BELT SIGN ..... ON
BEACON ..... ON

AFTER START

ANNUNCIATOR ..... CKD
IGNITION ..... *OFF
ELECTRIC POWER ..... *CKD
APU AIR ..... *(AS REQ)
AIR CONDITIONING SUPPLY SWITCHES ..... *AUTO
PNEUMATIC X-FEED ..... *ONE CLOSED
TRANSFER PUMP & HYDRAULIC SYSTEMS .... *ON & CKD

TAXI

FLAPS ..... **(SETTING)
TRIM ..... **(SETTING)
EPR & AIRSPEED BUGS ..... **(SETTINGS)
ANTS ..... (AS REQ)
FLIGHT INSTRUMENTS ..... **(HDG) & SLAVING
CONTROLS & ELEVATOR POWER ..... *CKD-TOP
CKD-BOTTOM

DELAYED ENGINE START

BRAKES & IGNITION ..... (AS REQ) & ON

DELAYED AFTER START

ANNUNCIATOR ..... CKD
IGNITION ..... *OFF
ELECTRIC POWER ..... *CKD
APU AIR ..... *OFF
AIR CONDITIONING SUPPLY SWITCHES ... *AUTO

ENGINE ANTI-ICE & FUEL HEAT ..... (AS REQ)
PNEUMATIC X-FEEDS ..... *CLOSED
APU ..... *(AS REQ)

BEFORE TAKEOFF

FLIGHT ATTENDANT ..... *NOTIFIED
TRANSPONDER ..... *ON
ANNUNCIATOR ..... CKD
IGNITION ..... ON

CLIMB

NO SMOKE SIGN ..... *(AS REQ)
IGNITION ..... *(AS REQ)
FUEL PUMPS ..... *(AS REQ)
CABIN PRESSURE CONTROLLER ..... *CKD
SYNC ..... *ON
HYDRAULIC PUMPS ..... *OFF & LOW
FLAP TAKEOFF SELECTOR ..... *STOWED

IN-RANGE

ALTIMETERS ..... **(SETTING) & X-CKD
EPR ..... *(GA)
AIRSPEED BUG ..... **(SETTING)
SEAT BELT SIGN ..... *ON
CABIN PRESSURE CONTROLLER ..... *CKD
HYDRAULIC PUMPS ..... *ON & HIGH

BEFORE LANDING

NO SMOKE SIGN ..... *ON
IGNITION ..... *ON
FUEL SYSTEM ..... *SET FOR LANDING
SYNC ..... *OFF
GEAR ..... *THREE GREEN
SPOILERS ..... *ARMED
AUTO BRAKES ..... (AS REQ)

FLAPS ..... *(SETTING)*

AFTER LANDING

SPOILERS ..... *DOWN
FLAPS ..... *(AS REQ)
ICE PROTECTION ..... *OFF
IGNITION ..... *OFF
APU ..... *(AS REQ)
PNEUMATIC X-FEED ..... *ONE OPEN
RADAR & TRANSPONDER ..... *OFF & STANDBY
APU AIR & ELECTRIC POWER ..... *(AS REQ) & CKD

PARKING

AIR CONDITIONING SUPPLY SWITCHES ... *OFF & AUTO
PNEUMATIC X-FEEDS ..... *OPEN
FUEL CONTROLS ..... OFF
SEAT BELT SIGN ..... OFF
BEACON ..... *OFF
CHOCKS & BRAKES ..... (AS REQ)
AUX & TRANSFER PUMPS ..... *OFF
FUEL PUMPS ..... *(AS REQ)
WINDSHIELD HEAT ..... *(AS REQ)
LOGBOOK ENTRY ..... (AS REQ)

TERMINATING

EMERGENCY LIGHTS ..... *OFF
PITOT HEAT ..... *OFF
AIR CONDITIONING PANEL ..... *(AS REQ)
RADIOS & GALLEY POWER ..... *OFF

SECURING AIRPLANE AT NON MAA STATIONS

APU ..... *OFF
OUTFLOW CONTROL ..... *(AS REQ)
BATTERY SWITCH ..... *OFF

Included in this standard terminology should be a dictionary of abbreviations to be used whenever abbreviations are needed. To quote MIL-M-7700C: "The glossary of each manual shall contain a list of the abbreviations used in the manual, except for normally accepted and understood abbreviations such as ac, dc, and rpm." Although the MIL SPEC mentions "manual" specifically, the same would apply to checklists, since they derive from the flight manuals. In MIL-M-7700C there is a list of approved abbreviations, and MIL-STD-12D is dedicated to abbreviations. Some of them are different from those used in civilian aviation, but a lexicon for standardization would resolve these differences and create a set of abbreviations, with a basis in the MIL SPECS, for industry use.

We feel that in the interest of standardization, and to ease crew transition from one aircraft type to another, a lexicon of common terms and abbreviations must be developed.

CLARIFICATION OF "NORMAL," "ABNORMAL," AND "EMERGENCY"

There must be clear definitions of what are to be regarded as "NORMAL," "ABNORMAL," and "EMERGENCY." The manufacturer of one imported aircraft flown by the regional airlines includes 39 "EMERGENCY" checklists out of a total of 82 checklists. An example of one checklist classified improperly as an "EMERGENCY," in our opinion, is "UNPRESSURIZED FLIGHT."

One set of definitions of "ABNORMAL" and "EMERGENCY" has been created by Flight Safety Canada, Ltd.

> "EMERGENCY PROCEDURES"—"This section deals with foreseeable but unusual situations in which immediate and precise action may be required by the crew."
>
> "ABNORMAL PROCEDURES"—"Procedures in this section address foreseeable situations involving failures, in which the system's redundancy or selection of an alternate system will maintain an acceptable level of airworthiness."

In MIL-M-7700C there are definitions for "WARNINGS" and "CAUTIONS" which could be borrowed for "ABNORMALS" and "EMERGENCIES."

> "WARNING"—"Operating procedures, techniques, etc., which could result in personal injury or loss of life if not carefully followed."
>
> "CAUTION"—"Operating procedures, techniques, etc., which could result in damage to equipment if not carefully followed." To the latter, we would add, "and if not carefully followed, could eventually lead to personal injury or loss of life."

The Flight Safety definitions are not as strongly worded as the ones in the MIL SPEC, but do convey the sense of urgency, nonetheless. A combination of these definitions would satisfy the need to provide strict guidelines for use by aircraft manufacturers and airlines in the preparation of aircraft flight manuals and checklists.

MANAGEABILITY OF CHECKLISTS

Paper checklists should be of an easily used and stowed size. We recommend in "PRINT SIZE and STYLE" that card checklists be 8 1/2" x 11," either laminated or trifold. We also recommend, if possible in keeping with the recommendations on print size and style, that there be a combination on one card of "Normal" and "Emergency" checklists. One group on one side of the card, one on the other. One airline uses this combination. The combination makes the task of location of needed checklists far easier. However, in this case, the recommendations for print size and style are not met.

To retain the recommended size of print we recommend that there be two cards, one for "Normal" checklists, and one for "Emergency" checklists — color-coded for easy identification. These should both be kept in the same, easily accessible place in the cockpit. These two groups of checklists are the ones that should allow ready access. The "Normal" checklists are used all the time in daily operation. "Emergency" checklists will not be needed on a steady basis, but should be immediately available when they are needed.

It is normal practice with many airlines to keep "Abnormal" checklists in the flight manual. Since they are not needed on an immediate basis, this access is adequate.

We recognize that these guidelines do not address the concern of the proper use of checklists by pilots. However, we feel strongly that if easily usable, readable checklists are available to pilots, the tendency to neglect or to misuse checklists may be reduced.

FIGURE A-3. DC-9 CHECKLIST

DC-9 NORMAL PROCEDURES CHECKLIST

BEFORE STARTING ENGINES

LOG BOOKS AND SEL.....CHECKED
* RUDDER PEDALS AND SEATS.....ADJUSTED AND LOCKED
* WINDOWS.....CLOSED AND LOCKED
O_2 PANELS/MASKS/INTERPHONE/GOGGLES.....SET AND CHECKED
EMERGENCY LIGHTS.....ARMED
* PROBE HEAT.....CAPT
* WINDSHIELD ANTI-ICE.....ON
ANTI-SKID.....OFF
PRESSURIZATION.....AUTO (UP) AND SET
* AIR COND SHUTOFF.....AUTO
* FLIGHT GUIDANCE PANEL.....SET AND CHECKED
* FLT INSTR/SWITCHES/BUGS.....SET AND CROSSCHECKED
* FUEL PANEL/QUANTITY AND DISTRIBUTION.....SET/___LBS AND CHECKED
GEAR HANDLE AND LIGHTS.....DOWN AND GREEN
* TRANSPONDER.....SET
* STABILIZER TRIM.....SET
SPOILER LEVER.....RET
THROTTLES.....CLOSED
FUEL LEVERS.....OFF
FLAPS/SLATS.....UP/RETRACTED
* AILERON/RUDDER TRIM.....ZERO/ZERO
* PARKING BRAKE/PRESSURE.....PARKED/NORMAL
* SHOULDER HARNESSES (If Operative).....ON
* FLIGHT FORMS.....CHECKED
* NO SMOKING SIGNS.....ON
* SEAT BELT SIGNS (5 Minutes Prior To Departure).....ON

PRIOR TO ENG START OR PUSH-OUT

GALLEY POWER.....OFF
ENGINE IGNITION.....CONTIN
FUEL PUMPS.....ON
AUX HYDRAULIC PUMP.....ON
ANTI-COLLISION/EXTERIOR LIGHTS.....ON/AS REQUIRED
DOOR ANNUNCIATORS.....OUT
AIR CONDITIONING SUPPLY SWITCHES.....OFF

TAXI

BEFORE TAXI

GALLEY POWER.....ON
ENGINE ANTI-ICE.....AS REQUIRED
HYDRAULIC PUMPS.....CHECKED AND HI/ON
APU.....AS REQUIRED
PNEU X-FEEDS (One Engine Taxi).....L CLOSED/R OPEN

TAXI

AIR CONDITIONING SUPPLY SWITCHES.....AUTO
ANTI-SKID (After Leaving Ramp Area).....ARM
R ENG (One Engine Taxi).....SHUTDOWN
FLIGHT CONTROLS.....CHECKED
FGS.....T/O MODE

BEFORE TAKE-OFF

Use Mechanical Checklist

AFTER TAKE-OFF – CLIMB

After Airplane Clean Up When Workload Permits.

GEAR.....UP AND NO LIGHTS
SPOILER LEVER.....DISARMED
AUTO BRAKES.....OFF/DISARMED
FLAPS AND SLATS.....UP/NO LIGHTS
PRESSURIZATION AND AIR COND.....CHECKED

10,000 Ft. MSL

ENGINE IGNITION.....AS REQUIRED
FUEL SYSTEM.....CHECKED
STERILE COCKPIT.....CABIN CHIME
ALTIMETERS.....RESET AND CROSSCHECKED
HYDRAULIC PUMPS.....LOW/OFF

18,000 Ft. MSL

EXTERIOR LIGHTS.....AS REQUIRED
ALTIMETERS.....RESET AND CROSSCHECKED
(Outside Continental U.S., Reset At The Specified Transition Altitude Obtained From Charts Or ATC.)

APPENDIX B

Advantages and Disadvantages of Checklist Types

Type of checklist	Advantages	Disadvantages
Mixed - paper-slide or paper-sw/lt	1. Positive check on checklist progress for those lists on the mechanical portion 2. The lists on the mechanical device can be interrupted without losing track of progress	1. Necessitates the use of two sets of lists 2. Slide or switch/light combination takes up cockpit real estate
Paper	1. Easy to use and move around as the checklists are done 2. Easy to stow 3. Inexpensive to reproduce 4. Inexpensive to update	1. Easy to mark on and mess up 2. Becomes worn easily 3. Easy to misplace or remove from the airplane 4. May be difficult to use under poor lighting conditions
Laminated card	1. Tough and hard to destroy 2. Difficult to mark on and mess up 3. Fairly easy to stow 4. Remains legible longer than paper checklists	1. More expensive to produce than paper lists 2. Bulky in comparison to a folded paper checklist
CRT	1. Can't lose checklists 2. Can present systems schematics in the case of "Abnormal" or "Emergency" checklists 3. Color-coded for ease of use 4. No stowage problem	1. May displace another display such as radar 2. Requires a lot of "heads-down" time 3. Takes up cockpit real estate 4. Can be cumbersome to find a list or go back to a point in a list
Scroll	1. Permanent fixture - can't get lost 2. Promotes "heads-up" posture 3. Relatively easy to make changes to checklists 4. Stows out of the way on the glare shield 5. Easy to mark progress	1. Can be hard to read (size of print and distance from the viewer, and some are not lighted at night) 2. Difficult to go back to a prior item on a checklist
Checklist "booklet"	1. Groups all checklists together - including the "Abnormal" and "Emergency" checklists 2. If properly tabbed, makes it easy to find any needed checklist	1. Can be bulky on aircraft with a large number of lengthy checklists

APPENDIX C

Summaries of ASRS Special Requests 1403 and 1417

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
1.	LRG	No nose wheel steering, had to be towed off runway	Use of emergency and normal checklists - missed one item on the "descent" checklist
2.	SMA	Gear up landing	No written checklist available - interruption from pilot-passenger
3.	SMT	Unauthorized entry onto runway	Busy finishing checklists and misheard "clearance on request" for "cleared on course"
4.	MLG	Unauthorized runway crossing	Busy running checklists, poor crew coordination
5.	MLG	Possible traffic conflict, early turn to SID heading	Reading checklist instead of paying attention to SID, poor crew coordination
6.	LTT	Aborted takeoff	Didn't turn on water injection system for takeoff, poorly designed checklist item, lack of understanding of standard procedures
7.	LRG	Departed 10,000 lbs. light on fuel, returned to airport	Busy doing checklists and no one verified the proper fuel loading - lack of clear procedures for fuelers to use and crews to verify proper fueling
8.	MLG	Unable to pressurize after takeoff, emergency declared	Pack switches not on, checklist item not accomplished, also not caught by the F/O on the quick check prior to declaring an emergency, found subsequently
9.	WDB	Altitude excursion and request for immediate turnaway from weather because of loss of F/O altimeter, flight instruments, and radar	F/O flying, Capt. and S/O doing an abnormal electrical checklist, one part of the procedure knocked off the F/O instruments and radar at the time they were to penetrate a line of weather
10.	WDB	Deviation from assigned SID, started to fly the wrong SID	Confusion during time of reading checklists prior to takeoff and receiving runway and SID assignment changes without programming in the FMS
11.	LRG	Crossed hold-short line but didn't quite have a runway incursion	Too busy with short taxi distance, unfamiliarity with taxi route, and amount of checklist to be accomplished
12.	MLG	Abnormal lights on takeoff, engine fire warning after takeoff, crew continued to destination	Engine fire bell went out and all engine indications normal, had been prior work on and abnormal lights for bleed air problems, did "air cond. supply temp hi" checklist, later maintenance found a 1" hole in the engine due to starter reengaging
13.	MDT	Altitude overshoot in emergency	Loss of pressurization, emergency descent, trying to control cabin altitude and do emergency and abnormal checklists and get clearance from center, "1,000 ft. above" didn't get called
14.	LTT	Total electrical failure with emergency battery activation, spoilers were deployed and would not retract, diverted to long runway for landing and blew main gear tires on landing	Bad freon air-conditioner installation resulting in power loss, used emergency procedures

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
15.	LRG	Hydraulic problem after takeoff, dumped fuel, declared an emergency and returned to land	"A" system hydraulic failure on takeoff, subsequent multiple abnormals due to air conditioning problems, emergency declared with return to airport, equipment standing by and tow to the gate
16.	SMA	Aircraft lost partial power on takeoff, hit powerline and made gear-up landing on grass area of airport	No time for emergency checklists, cause of loss of power under investigation
17.	WDB	Aborted takeoff due to engine disintegration with associated fire warning	Aborted, performed emergency checklist, checked by fire crew, taxiing to gate fire crew noticed further engine fire which they extinguished, taxied to the gate
18.	SMA	Gear retraction during takeoff roll, aircraft dropped to runway	Failure to follow proper checklist, instructor giving dual instruction gave pilot improper instructions regarding a short field takeoff and the proper positioning of the gear handle
19.	SMA	Gear up landing	Pilot extended flaps on final instead of gear and didn't use a checklist to assure gear down, ignored warning horn assuming it was a stall warning near the ground and of no consequence
20.	LRG	Runway incursion on rollout causing aborted takeoff by a MLG	Called for after landing checklist on rollout, misunderstood "hold short" instructions which had been acknowledged by the F/O, started across runway, too much confusion
21.	WDB	Pilot not flying shut down both engines in improper response to a warning light, aircraft was between 1,200' and 1,500' AGL after take-off, able to restart engines and continue	No use of checklist, highly experienced Capt. tried to do an abnormal procedure without reference to the checklist and without coordinating with the F/O who was flying
22.	SMT	Altitude overshoot on departure	PIC flying, check-pilot in the right seat acting as F/O and known for not encouraging checklist use or altitude callouts, aircraft sometimes flown as a single pilot operation, poor coordination and no clear direction from the PIC as to procedure to be followed
23.	MLG	Aircraft returned to land, nose gear pin installed	Nose gear pin installed during tow to gate, during checklist the crew checked for gear pins, felt two and thought it was three
24.	MLG	Altitude alert activated in cruise, descent begun and oxygen masks used	Crew did not turn on the pressurization switches when doing the checklist, thought they had but missed them
25.	WDB	Landed wrong runway from an ILS approach	Crew busy changing frequencies, doing checklists, etc., aircraft had been flown fully automated, on crosscheck with raw data found improper ILS alignment, automatic go-around mode engaged, Capt. called for correction on ILS, took over aircraft and landed on the wrong runway in poor visibility
26.	WDB	Unable to control cabin altitude, made a descent to control it	Found air conditioning pack switches off, the rest of the checklist had been performed properly but those had been missed

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
27.	WDB	Initiated a go-around at 500' AGL because of gear not down	Crew had not fully configured the aircraft for landing by extending the gear and final flaps, missed those items on the checklist and got the GPWS at 500'
28.	MLG	Poorly designed and potentially dangerous checklist	"Generic" checklist used for an entire fleet, has no logical flow pattern and requires a PA announcement on final in contravention of the FAR sterile cockpit rule, has been approved by the POI
29.	SMA	Aircraft moved forward after start and hit the nearby fuel pump	Pilot used aircraft checklist which called for throttle to be pulled out 1/2" on start, regardless of whether warm or not, aircraft parked close to fuel pump, unable to control
30.	MLG	Go-around due to GPWS activation at 500'	Cockpit confusion due to monitoring close traffic on parallel approaches, gear handle not fully in down detent, when fully in detent GPWS continued to sound, turned off pax O2 instead of GPWS because of proximity of switches in nonstandard cockpit configurations of the same model aircraft
31.	SMA	Gear up landing	Gear was not down and locked despite the use of a checklist, pilot also did not utilize his normal GUMPS check
32.	SMA	Gear up landing	Used checklist but missed the gear, CFI in the aircraft didn't GUMP the aircraft, but owner claimed to have done that twice
33.	SMT	Misuse of transponder code misleading center controller with possible altitude conflict	Sloppy use of the checklist in entering transponder code
34.	LRG	Altitude overshoot	Poor crew coordination, disregard of CRM and proper procedures by Capt. (on one takeoff the checklist was just finished about 10 kts. prior to Vr)
35.	LRG	False fire warning, causing use of emergency procedures and evacuation of aircraft after landing with minor injury to passenger	After checking, there was no apparent fire, crew had used emergency checklist and fought supposed fire, declared an emergency and evacuated the aircraft
36.	MLT	Aircraft made inadvertent slats extended and flaps up T/O, no serious consequences	Flaps had been programmed when checklists were done, flaps raised when taxiing in proximity of a large pile of dirt, flaps never extended, T/O warning horn not programmed to sound without flaps since flaps retracted-slats extended T/O is one configuration for that aircraft
37.	SMA	Aircraft landed gear up	Pilot forgot to extend gear, didn't use normal checklist procedure with a GUMP backup due to fatigue, inop circuit breaker for gear warning horn
38.	SMA	Aircraft landed gear up	Pilot didn't do GUMP check, inop gear horn, distraction in the pattern

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
39.	MLG	Aircraft departed on wrong runway	Unexpected aircraft change with subsequent rushing and half-done job of checklists, poor crew coordination, hearing clearance but not monitoring Capt.'s taxiing, Capt. late starting second engine after single engine taxi with rushed and incomplete checklist and subsequent confusion
40.	MLG	Incorrect V speeds set and not caught until during the T/O roll	Operating rushed, late at night and fatigued and gave standard checklist response rather than thorough check
41.	LRG	Aborted T/O due to flaps not set	Had read checklists and responded but the flaps weren't set, disrupted diurnal rhythm - crew had flown late sequences all month and this trip had all early checkins
42.	MLG	Altitude overshoot on SID	During abnormal start procedure premature pulling of external electrical power caused automatic bug and altitude reminder resets, improper bug set was caught on the checklist, altitude reminder was not
43.	MLG	Aircraft took off with gear pin installed, returned to land	Gear pin flag removed and stowed in cockpit by contract ground personnel, pin still remained installed, crew on doing checklist counted three red flags but didn't check to make sure that a pin was connected to each
44.	SMT	Aircraft landed gear up	Crew preoccupied with approach to unfamiliar airport, didn't do final check, gear horn sounded just at the flair with power reduction
45.	LTT	Overweight landing	Crew fatigued and rushed, improper fueling not caught prior to departure, no mention of fuel load on any of the checklists
46.	SMA	Aircraft landed gear up	Only used checklist partially, checklist difficult to read at night, busy monitoring traffic at busy airport, neither pilot nor instructor caught the error
47.	LRG	Aborted T/O, flaps not set for takeoff	Fatigued crew with other distractions neglected to extend flaps and didn't read the taxi checklist
48.	MLG	Engine failure and separation during climbout	Cause unknown at present, emergency checklist performed, emergency declared, landing without further incident
49.	SMT	Gear not down for landing, minor damage from runway contact during a successful go-around	Pilot had gear down early in the approach, raised it because of windshear encounter, with bad weather and other distractions, did not extend gear again, poor instrument scan, lack of checklist or GUMP use
50.	WDB	Aircraft off course by 20 miles or so	Using automated systems and Omega, both FMS and Omega had gross errors, both systems previously written up in the log for maintenance action
51.	SMT	Red gear warning light on approach	Unable to extend gear normally, used emergency procedure and checklist

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
52.	MLG	Failure to shut down right engine prior to leaving aircraft	Crew claims to have used shutdown checklist, also went to belly baggage bin before leaving and didn't notice engine running
53.	MDT	Flaps not fully retracted after landing, flaps damaged by passenger bus driving under the wing on the ramp	High demands on crew by ATC on rollout to clear the runway quickly, during after landing checklist the F/O was interrupted many times and didn't retract flaps fully, SILENT checklist without other crew monitoring
54.	LRG	Aircraft had to level during climb due to cabin altitude warning horn to allow cabin to catch up and to pressurize	Too short a time period during taxi to accomplish all items satisfactorily, including checklist, missed the air conditioning pack switches, should have delayed to accomplish everything
55.	MDT	Engine fire with return to departure point and emergency declared	Used engine fire emergency checklist, looked for single engine landing checklist and couldn't find, checklists in the process of revision with conflicts between some lists, FAA aware of the problems but no action to date
56.	MLG	Aircraft left with less than required fuel, no serious consequences	Distracted attention in the cockpit during the reading of checklist
57.	SMT	Aircraft landed gear up	No checklist, gear warning horn did not operate
58.	LTT	Aircraft made go-around during an ILS approach, anomalies in instrument readings	Crew fatigue, missed proper settings on nav receivers, no items on checklist to cover this
59.	MDT	Aircraft departed with incorrect fuel load, had to divert to alternate to get fuel	Distraction in the cockpit at the time the checklist was being read, holding for fuel to be loaded, rush to make schedule, fuel last item on the crew acceptance checklist and not on any other checklist for a crosscheck
60.	SMT	Aircraft landed gear up	No checklist, task saturation at low level, gear handle used but gear didn't extend, gear warning horn inop, didn't confirm gear green lights
61.	SMA	Aircraft landed gear up	Pilot monitoring hot air balloons and other traffic, sun in his eyes, lowered flaps instead of gear, didn't get warning horn due to high manifold pressure because of ATC-requested high speed on approach
62.	MLG	Complaint of passengers smoking in the aisles and seatbelt sign off prior to completion of flight	Crew not using checklist correctly and not monitoring passenger conduct
63.	LTT	Inflight engine shutdown due to loss of oil pressure and quantity, emergency declared	Crew had a low oil pressure warning and ignored it because of previous transducer failures on this aircraft type, low oil quantity and pressure caused a flame-out, did emergency checklist
64.	MLG	Altitude excursion on final approach	Aircraft stall warnings systems activated, crew followed stall procedures including lowering the nose to pick up speed for configuration, system had failed, aircraft was not in a stall

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
65.	MLG	Aircraft aborted T/O due to high wind noise around Capt.'s window	Window design such that the handle appeared properly in place but the securing dogs weren't properly in place, window is not a checklist item or it might have been noticed
66.	LRG	Didn't make required log book entries	Had an asymmetric flap procedure on landing, used abnormal list and normal, during the confusion and subsequent relief of being on the ground, they forgot
67.	MLG	Gear doors didn't retract on raising the gear, damage to doors on subsequent landing	Crew did the checklists required for unretracted gear doors, used all published procedures
68.	WDB	Aircraft unable to pressurize, descended with special handling	Switch not in proper position to allow pressurization, was answered for on the before-taxi checklist but not properly checked
69.	LRG	Emergency descent due to loss of pressurization	Failure of door seal, used all appropriate checklists and landed without incident
70.	SMA	Aircraft landed gear up	Busy watching traffic ahead on final, didn't extend gear or do GUMP check
71.	MLG	Cabin altitude horn sounded, unable to control cabin altitude, emergency descent with altitude overshoot	Improper altitude put in altitude reminder while F/O was busy trying to do the checklists and talk with ATC
72.	MDT	Aircraft took off with cockpit door open and flight attendant still stowing baggage	Flight attendant supposed to close cockpit door, inadequate flight attendant training, cockpit door not on any checklist
73.	LTT	Aircraft lost right engine cowling and had right engine failure at 1,000' in climb	Latches to the cowl are supposed to be checked on preflight, pilot claims he did, all emergency procedures followed, uneventful landing
74.	MLG	Aircraft had smoke in the cockpit and pressurization problems, descended and continued to destination	Did the electrical smoke or fire checklist, isolated the problem, continued to destination and landed with the emergency equipment standing by on the ground
75.	LRG	Go-around due to no gear extension and GPWS warning	Crew got behind the program with an approach in the weather and a change of runways during approach, missed the gear on the checklist
76.	MLG	Aircraft landed with the cabin not secured and with flight attendants not in assigned landing positions	Checklist still reflects the use of a call button to alert the flight attendants at the time the no-smoke sign was turned on - with the new smoking regs, the no-smoke sign is on all the time for this airline - checklist or operating policy should be revised
77.	LRG	Possible health hazard to ground personnel from operating radar	After a demanding flight the crew did the proper checklists and thought they had turned the radar to standby - radar had different switching than what they were used to and may not have been turned to standby
78.	SMT	Aircraft aborted takeoff from 40' in the air resulting in aircraft damage	Pilot took off with the control lock on the yoke - didn't use checklist to back up flow pattern

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
79.	LRG	Aircraft depressurized requiring use of rapid depressurization and explosive depressurization checklists and diversion to a nearby field	Cracks in the cabin in the wheel well area probably due to aircraft age
80.	MLG	Aircraft declared an emergency on climbout and returned to land	Engine loss on climbout with use of emergency and normal checklists
81.	MLG	In climb the aft cargo door light illuminated, unable to pressurize, continued to destination and landed	Cargo door light not noticed during pre-takeoff checklists, continued due to below landing minimums at departure point
82.	MLG	Aircraft unable to control pressurization, horn sounded, masks dropped, emergency declared	Loss of pressurization, cause unknown, used emergency checklists and procedures, continued to destination at lower altitude
83.	MLG	Didn't control cabin altitude, got passenger oxygen masks, recovered pressurization, continued to destination climbing above 25,000' illegally (due to no availability of automatic oxygen mask presentation) to avoid weather	Bleed switches not on and not noticed out of the proper position on the checklist
84.	LTT	Near mid-air collision, took evasive action	Busy doing checklist for descent and both had heads inside the cockpit, although under positive control, the controller didn't point out the traffic
85.	SMA	Aircraft landed gear up after an aborted landing and go-around	Too much float on a hot day, went around. Didn't put gear down for second approach, did a GUMP check and missed the gear, gear horn didn't work because of high approach power setting
86.	MLG	Loss of pressurization and emergency descent	Lost both packs simultaneously, used emergency checklists and descent, donned oxygen masks, both packs came back on the line, continued to destination, cause unknown
87.	MLG	Jetway shifted causing minor aircraft damage, blamed on aircraft rolling	Brakes were set per the securing checklist
88.	LRG	Near overtemp on starting engine #1	At a stop on a through flight maintenance had been working on a thrust reverser problem, start levers had been left in idle rather than cutoff during the work, this was not caught prior to start since "start levers to cutoff" is not on the before start checklist on a through flight
89.	MLG	Aircraft rolled forward on engine start, brakes applied suddenly causing flight attendants to fall with two sustaining minor injuries	Brakes not set during checklist, chocks pulled by ground crew without informing cockpit crew, non-standard procedure for use of parking brakes prior to engine start
90.	MLG	Damage to aircraft tow bar during pushback	Abnormal start due to APU electrics inop, no specific checklist to cover, used normal flow pattern during an abnormal start

SECOND GROUP OF REPORTS FOLLOWS ON PAGE C-9

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
1.	MLG	Aircraft landed without clearance from the tower	Two-man crew, very busy trying to locate an unfamiliar airport, doing checklists, etc., didn't switch frequencies
2.	MLG	Aircraft overshot altitude in descent, on autopilot	Autopilot sensing taken off F/O altimeter which was set 1 inch too high (30.79" vs. 29.79")
3.	MLG	Aircraft overshot altitude in climb	Aircraft on test flight, two-man crew, pilot flying new on aircraft, pilot not flying overly busy with extensive test flight checklist and didn't call 1000' before the altitude
4.	WDB	Aircraft overshot altitude on SID	Preoccupation with the checklist and no call for 1000' before the altitude
5.	MLG	Aircraft overshot altitude on descent	Two-man crew fairly new to the airplane, busy running checklists and other duties, knocked off altitude hold by mistake and didn't catch it until after descent below assigned altitude
6.	MLG	Aircraft emergency evacuation leaving the ramp	Alleged right engine fire, ran emergency checklists and did emergency evacuation
7.	MLG	Aircraft overshot altitude in climb	Didn't reset altimeters at 18,000' and didn't catch it on the checklist
8.	MLG	Runway incursion during taxi	Crew busy doing checklists and briefing
9.	MLG	Altitude excursion, aircraft on autopilot	Crew busy doing checklists and other duties, did not catch the fact that the autopilot had gone to another mode and started to climb
10.	MLG	Near mid-air collision, took evasive action	Aircraft level, crew busy changing radio and doing checklist, looked up to see small aircraft very close at the same altitude, no mention by the controller
11.	MLG	Emergency descent made and emergency declared, couldn't control cabin altitude	Did emergency checklists, auto pressurization lost, regained control with manual pressurization, continued to destination
12.	MLG	Near mid-air collision, no time for evasive action	Aircraft in level flight under positive control, did outside check, dropped eyes to checklist, looked back up to see an aircraft within 150' crossing at the same altitude, no mention by the controller although the controller did say afterwards he had the aircraft on radar
13.	WDB	Aircraft overshot turn to final	Crew busy programming the FMC and doing checklist, got behind the airplane and didn't get into the slot until 1000'
14.	WDB	Aircraft aborted T/O	F/O sliding window came open on T/O, not latched properly, item not on checklist for positive check
15.	WDB	Questionable descent clearance	Crew busy doing checklists, handling multiple radios, etc., got a descent clearance from one controller, a frequency change, and the following controller questioned the altitude

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
16.	MLGA	Aircraft undershot crossing altitude	Crew busy getting ATIS, working radio, doing checklists, tuned wrong VOR frequency, and didn't make crossing restriction
17.	MLG	Altitude overshoot on descent, aircraft on autopilot	Captain busy with checklist, F/O programmed the autopilot wrong and knocked off altitude hold
18.	MLG	Altitude overshoot on climb	Maximum performance climb, light aircraft, tired crew, busy doing checklist and working radio, didn't reset altimeter soon enough and went through the assigned altitude
19.	MLG	Altitude overshoot on climb	Late at night, long flight sequence, light, fast climbing aircraft, multiple frequency changes, doing checklist, didn't catch it
20.	WDB	Altitude overshoot in climb	Crew didn't reset altimeters to 29.92" at 18,000', distracted from the checklist by turbulence
21.	LRG	Aircraft missed crossing restriction	Due to multiple frequency changes and looking for traffic climb checklist was never done, and altimeters weren't reset
22.	MLG	Momentary application of heavy auto brake on landing, resulted in a very noticeable lurch during rollout	While doing the landing checklist the F/O inadvertently programmed the auto brake for T/O, due to darkness and having to do a 360 degree turn on final, the error was not caught
23.	MLG	Aircraft several thousand feet high on crossing restriction	Poor crew coordination, inexperience on the aircraft and that portion of the route structure for the captain, running the checklist
24.	MLG	Probable needless engine shutdown in flight, emergency declared with a precautionary landing short of the destination	While performing the checklist for an electrical abnormal, captain mistook an APU low oil pressure light for an engine low oil pressure light and shut down the engine, poor crew coordination while doing electrical abnormal and F/O was starting the APU
25.	MLG	Altitude overshoot on climbout	Captain had called 1000' before the altitude and got busy doing something else, F/O looked away to do something that wasn't called for on the checklist at that point and went through the altitude
26.	MLG	Altitude overshoot on climbout	Very short flight, frequency changes (both company and ATC), auto throttles not operating, doing checklists, overloaded two-man crew
27.	WDB	Altitude overshoot on descent	Busy two-man crew, set improper altimeter and overshot by 1000'
28.	MLG	Altitude overshoot on descent	Two-man crew doing checklists and other duties on descent for landing, altitude capture not set on autopilot, no altitude warning on the aircraft, caught by the crew after they had overshot
29.	MLG	Speed deviation on STAR	Captain handflying aircraft for practice, F/O doing checklists, handling radio, etc., both missed the speed restriction on the STAR
30.	WDB	Altitude undershoot in climb	Crew neglected to reset altimeters to 29.92" at 18,000', missed it on the checklist

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
31.	MLG	Near mid-air collision on arrival route, took evasive action	Crew doing checklists and crosschecking settings on instruments as per company policy, just missed other aircraft crossing the arrival route, no warning from the controller
32.	MLG	Altitude overshoot in climb	New capt., new copilot, new airplane, new airport, very rushed, rushed the checklists (missing an item), unfamiliarity with autopilot resulted in overshoot
33.	MLG	Altitude overshoot on descent	Forgot to reset altimeter leaving 18,000' in the descent
34.	MLG	Altitude overshoot on descent	Read in range checklist completely at 24,000 and missed the altimeter reset at 18,000', premature completion of the list
35.	WDB	Altitude overshoot on descent	Two-man crew, between 310 and 180 had five speed changes and two hdg. changes, one altimeter got reset, the one of the pilot flying did not; in addition, after the overshoot there were three more speed changes, two more hdg. changes and three runway changes (the last one taking place at 400' on final), THIS IS RIDICULOUS
36.	MLG	Aircraft almost aligned with the wrong runway for landing, FAA check airman on board made no comment, caught the error in time	Capt. busy looking for airport, running checklists and helping recent upgrade copilot
37.	MLG	Aircraft almost departed on a runway which was too short for their weight, caught by the company and relayed by the tower controller	Runway was the longer of the two and into the wind, but had a terrain restriction, crew was busy doing checklists and tending to a passenger problem and didn't actually check the performance charts for the runway
38.	WDB	Crew returned to ramp to have an extended spoiler fixed, spotted by crew of a following aircraft	Taxiing with one engine shut down, holding off on checklist, takeoff position advanced by controller, rushed to complete everything and missed indicator light for partially extended spoiler
39.	MLG	Aircraft almost departed with seat belt sign off and correct takeoff power settings	Rushed turnaround, trying to beat a curfew, rushed checklists and missed items, caught on the taxi for T/O
40.	MLG	Altitude overshoot in descent	Training flight, instructor busy doing checklists and instructing, autopilot lost the altitude hold and neither pilot caught it until after the overshoot
41.	MLG	Aircraft crossed runway hold line during taxi after instructions to hold short, potential conflict	Two-man crew doing challenge and response checklists and required PA announcements and missed holding short
42.	MLG	Aircraft landed without clearance from the tower	Heavy traffic, a great deal of maneuvering close in, busy doing checklists, didn't switch over from approach to tower
43.	MLG	Altitude overshoot on climbout	Pilot flying new on the aircraft, pilot not flying busy with communications, traffic watch and checklists, pilot flying did not reset altimeter and it was not caught on the checklist

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
44.	MLG	After liftoff a door light came on and aircraft could not be pressurized, returned to land	On door light checks on the checklists on the ground the door light was not illuminated
45.	MLG	Minor overshoot on descent	Contributing factors were preoccupation with checklist and PA
46.	MLG	Altitude overshoot on descent	New capt. getting line operating experience, doing checklist, changing frequencies, getting ATIS, de-icing airplane, autopilot did not capture properly, also no altitude alert on this type of aircraft when it is on all the rest of the fleet, nonstandardization
47.	MLG	Altitude overshoot and excessive speed	Light aircraft with a fast climb, crew busy doing checklists, frequency changes, etc., got way behind the airplane, attempting mixed use of autothrottle and manual control unsuccessfully
48.	WDB	Altitude undershoot on climb and missed altimeter on approach	Sloppy use of checklists
49.	SMA	Possible near miss	Pilot had been in contact with approach, had been given a discrete code and cleared below the LAX TCA, approach did not pass on info to LAX, passed near inbounds to LAX that apparently did not see him
50.	WDB	Left engine running after the securing checklist and leaving the aircraft	Did not physically check that fuel control switches were in cutoff, fuel control switch positions easily confused
51.	SMT	Altitude overshoot, possible conflict with other traffic	Crew busy doing arrival prep such as PA, ATIS, checklists, etc., misunderstood altitude cleared to and descended too low
52.	MLG	Aircraft landed with considerable fuel imbalance	Crossfeeding taking place, did not reinstate proper fuel pump configuration before landing, should be an item on the checklist for fuel pump configuration
53.	LRG	Aircraft overshot approach course, corrected for normal approach and landing	Unintelligible controller instructions, interruptions of checklist, missed proper inbound course setting on resumption of checklist
54.	MLG	Altitude overshoot on descent	Descent on autopilot, checklists in progress, autopilot failed to capture altitude, recovered manually
55.	MLG	Flight departed with less than planned fuel load	Aircraft not fueled, did not properly check the fuel load on the pre-engine start checklist
56.	MLG	Altitude overshoot on descent for ILS	Aircraft programmed for automatic ILS approach capture, while crew was busy doing the before landing checklist the FMS intercepted the localizer and began a premature descent, corrected manually
57.	MLG	Aircraft would not pressurize in climb	Cabin altitude control lever in the wrong position, missed on checklist
58.	MLG	Partial hydraulic loss, manual gear extension	Used appropriate abnormal hydraulic checklist

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
59.	LRG	Altitude overshoot of 1000' in descent	Altimeter set incorrectly by 1", not caught on two checklists
60.	MLG	Altitude overshoot on climbout	Distracted by radio, setting instruments, and checklists, didn't make 1000' before altitude callout, altitude reminder sounded
61.	LRG	Altitude overshoot on descent	Crew busy getting ATIS, doing descent and approach checklist, set altimeter improperly, altimeter setting not checked with that issued by ATC
62.	WDB	Aircraft declared an emergency, smoke in the cockpit, diverted to land short of destination	Various annunciator warnings, smoke in the cockpit, used oxygen masks, ran normal checklists but no emergency checklists were mentioned
63.	MLG	Aircraft lost comm on an active runway, caused a go-around	Crew busy doing checklist and final items for T/O, didn't notice a comm switch in the off position
64.	MLG	Altitude overshoot in descent	Fatigue, descending in bright sunlight, hydraulic pump activation caused a voltage spike knocking off the autopilot altitude hold, also making PA announcement, crew did not notice autopilot not engaged when running checklist
65.	WDB	Aircraft landed without clearance	Approach during rough weather, crew busy controlling aircraft and doing checklist, dialed in wrong frequency and didn't catch it until on the ground
66.	MLG	Aircraft landed without clearance	Approach control didn't switch the flight over to tower, crew busy running checklist, etc., didn't catch it until on the ground
67.	MLG	Altitude overshoot on descent	Doing checklist, reset altimeter for local pressure when only cleared to 18,000', altitude alert is only triggered by captain's altimeter, not both, so didn't sound
68.	LTT	Near collision on a runway, aircraft cleared into position to hold on a runway where another aircraft had been cleared for T/O	Crew busy doing checklist but did hold short to check runway as everyone should, saw other aircraft rolling and held short
69.	MLG	Altitude undershoot in climbout	Altimeter not reset, crew busy running checklists and handling aircraft in bad weather, NEW CHECKLIST PROCEDURE HAS ALTIMETERS RESET FROM QFE TO QNH AT 10,000' - TOO LATE FOR ACCURATE USE WHEN ASSIGNED ALTITUDES BELOW 10,000'
70.	MLG	Altitude undershoot in descent, went below crossing restriction	New capt., low light level, high workload including running checklists, misread DME for crossing restriction, other pilot did not recheck on his chart
71.	MLG	Aircraft didn't make crossing restriction	Two-man aircraft, high work load including checklists, controller confusion as to a prior restriction
72.	MLG	Altitude undershoot in descent, missed crossing restriction	Pilot flying busy with aircraft in turbulence and icing conditions, non-standard crossing restriction, pilot not flying out of the loop doing the checklist and didn't catch the error

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
73.	MLG	Altitude overshot in climbout	Pilot not flying busy doing checklist during a high rate climb at low level, altitude alert nonstandard from other aircraft in the fleet, pilot flying distracted temporarily
74.	MLG	Altitude overshoot in climbout, aircraft would not pressurize	Inadequate preflight and checklist use didn't catch locked open outflow valves, aircraft wouldn't pressurize and momentarily distracted crew attention from the altitude
75.	WDB	Wild autopilot oscillations in flight, corrected by going to manual control	Crew didn't turn on pitot heat, didn't catch it on the checklist, pitot tube iced up causing airspeed indication loss which sent incorrect speed to the air data computer resulting in rudder inputs for lower speeds when aircraft was at high speed
76.	MLG	Passed hold short point on a taxiway cutting off another aircraft	Two-man crew busy doing checklists and working ground and company radio, capt. misunderstood the taxi instructions and F/O didn't monitor closely enough because of other duties
77.	MLG	Altitude overshoot in climbout	Pilot not flying reading the checklist, failed to call 1000' before the altitude, ACARS message came across at the same time as they hit the assigned altitude
78.	MLG	Altitude overshoot in climbout, not caught by controller	Crew busy doing checklist and other duties, wrong altitude set in the altitude reminder, overshot and in the overshoot received a clearance to higher altitude
79.	WDB	Altitude overshoot in descent	Two-man crew busy in arrival procedures in busy area, bad weather, copilot busy doing comm, etc., capt. flying aircraft, programming the computer and doing checklists, missed altimeter reset at 18,000'
80.	MLG	Possible missed crossing restriction on both altitude and speed	Aircraft developed a pressurization problem in descent, crew busy doing abnormal procedure and flying aircraft missed crossing restrictions, but at the same time the controller gave them new altitude and heading which cancelled prior restrictions
81.	MLG	Altitude overshoot in climbout	Lower altitude assigned than original clearance when aircraft was almost at the new assigned and at a high climb rate, also distracted doing the checklist and altimeter didn't get reset
82.	MLG	Altitude undershoot in climbout, missed crossing restriction	Changes in altitude clearance by departure, crew busy doing checklist and other departure duties and turned prematurely resulting in lower altitude at crossing point
83.	MLG	Complaint concerning close parallel approaches	Reporter suggests staggering aircraft, in addition to being alarming to passengers it distracts from checklist and other duties
84.	WDB	Aircraft experienced multiple electrical failures, declared an emergency and landed short of destination	Proper use of abnormal, emergency and normal checklists
85.	MLG	Runway incursion	Aircraft had been cleared to hold short, F/O busy doing checklist and not listening, capt. misunderstood clearance

	AIRCRAFT TYPE	OCCURRENCE	CAUSE
86.	MLG	Engine oil leak caused further engine problems resulting in shutdown, other generator didn't pick up the lost load	Confusion in the cockpit due to nonstandardization of fleet, compounding problems, controller queries during a busy time, DIFFICULTY IN LOCATING THE EMERGENCY CHECKLIST
87.	WDB	Aircraft had to return to land due to two cargo doors open	Glass cockpit airplane, CRT wiped clean during the fire test in before starting engines checklist, misconception from training concerning recall of items to the CRT after start led to not seeing doors open light (crewmember had been led to believe that information was automatically displayed on power change over after start when it had to be recalled manually)
88.	MLG	Altitude undershoot on climb	Reset of altimeter at 18,000' is not on the checklist and the crew forgot it
89.	WDB	Aircraft took off over weight on a limited runway with antiskid inop	Rushed departure after maintenance delay working on antiskid, very short taxi with rushed checklists and engine start, message on weights to check dispatcher for reduced V1 speed, dispatcher referred them to manuals, manuals poorly set up to get info, two-man crew in busy environment unable to find info readily
90.	MLG	Cabin altitude climbed above 10,000' with no altitude warning horn, passenger oxygen masks deployed, returned to departure point	Proper use of appropriate checklists, inop cabin altitude warning horn and auto pressurization
91.	MLG	Aircraft overshot altitude on profile descent	Aircraft on autopilot with altitude hold engaged, pilot not flying doing checklist, altitude warning horn did not sound and autopilot did not capture altitude
92.	MLG	Altitude undershoot in climb	Altimeters not reset, didn't catch it in the checklist, low flight crew experience level, fleet nonstandardization
93.	MLG	Altitude overshoot during STAR	Flight crew distracted doing checklist
94.	MLG	Unauthorized landing	Crew given poor vectors to final and then turned on for a short, steep descent for landing, thought they heard a clearance which was for another aircraft - this aircraft uses a mechanical checklist with two blanks for "cleared for the approach" and "cleared to land" - thinking he had heard that, the copilot moved the slides indicating to the capt. that clearance was received
95.	WDB	Aircraft took off with gear pins installed and had to return to land	Crew distracted by maintenance while reading the checklist and missed the gear pins
96.	MLG	Aircraft took off with nose gear pin installed and had to return to land	F/O distracted on walkaround by new hire accompanying him, missed nose gear, PIC can't see gear pins in the cockpit as on other aircraft in the fleet, missed on the checklist
97.	LRG	Aircraft overshot altitude in climb	Aircraft in heavy weather, pilot flying called for the climb check, aircraft sustained a lightning strike, misread autopilot annunciators, and changed autopilot settings resulting in an overshoot
98.	MLG	Altitude overshoot during descent, less than standard separation with other aircraft	Two-man crew in busy environment, running checklists, etc., and altitude alert didn't sound

AIRCRAFT TYPE	OCCURRENCE	CAUSE
99. LTT	Aircraft landed without clearance	Busy airport, crew monitoring heavy in close proximity for the parallel runway, doing checklist, didn't contact tower
100. MLG	Altitude overshoot in descent	Crew didn't reset altimeter at 18,000', caught later when they ran the checklist after the overshoot
101. MLG	Aircraft landed on the wrong runway	Being vectored for one runway, confusion over controller comments concerning another, busy running checklist
102. MLG	Aircraft flew wrong radial on departure	Not set properly in nav instruments prior to departure and not caught on checklist
103. MLG	Aircraft missed crossing restriction	Concern over airport below minimums, discussing alternate plans, busy running checklist
104. MLG	Altitude overshoot of 1100' on climbout	Automated cockpit set to altitude capture with autothrottles set, crew doing checklist, autopilot did not capture
105. MLG	Aircraft missed crossing restriction	Crew busy doing checklist items, clearance misunderstood by the pilot flying and not caught in time by the other pilot
106. LRG	Altitude overshoot on short final	Doing checklist in turbulence, pilot flying altimeter set off 1", multiple approach control course and speed changes, mistake not caught until GPWS sounded and approach control altitude alert sounded
107. MLG	Altitude overshoot on climbout	Crew busy looking for traffic and doing checklist, new crew to aircraft in both seats, high performance climb with a 2000' assigned altitude
108. LRG	Altitude undershoot at top of climb and in cruise, not noticed until descent for landing, controller didn't catch	Crew new to the airplane, both used to three-man crew, now on a two-man aircraft, missed setting altimeters at 18,000' and didn't catch it on the checklist
109. MLG	Aircraft experienced loss of pressurization, made emergency descent and declared an emergency	Appropriate checklists used
110. MLG	Engine flame-out at altitude from fuel exhaustion, emergency declared, got engine relight at lower altitude	Ran the main tanks dry with a lot of fuel in the center tank, didn't have all the boost pumps on and didn't catch it on the checklist
111. MLG	Altitude deviation during approach	Two-man crew, very busy environment with many heading and speed changes, frequency changes, ATIS, reading the checklist - one pilot thought he heard a clearance and started down, clearance not confirmed because of frequency congestion
112. MLG	Altitude overshoot on climbout	Due to loss of partial aircraft systems and transfer of aircraft control and subsequent abnormal checklists altimeter was not reset at 18,000', the transition level altimeter reset is not on a checklist

AIRCRAFT TYPE	OCCURRENCE	CAUSE
113. WDB	Aircraft failed to pressurize, returned to point of departure	Neither air conditioning pack was operating, no checklist for that abnormal procedure, returned and found a start arm switch in the wrong position, didn't catch it on the checklist after starting engines, the only checklist for packs inop is found under the expanded checklist for rapid decompression (???)
114. WDB	Aircraft landed without clearance	Crew busy with tight approach and doing checklist, didn't contact tower until after rollout, tower didn't even know they had landed
115. MLG	Engine flamed out, single attempt at restart unsuccessful, landed short of destination	Used all appropriate checklists, abnormal, emergency, and normal
116. MLG	Aircraft taxied into position on an active runway, possibly without clearance	Confusion as to controller instructions, capt. called for last items on the before takeoff checklist which are normally done only when cleared into position
117. MLG	Near mid-air collision	Aircraft on approach, on autopilot and autothrottles, crew was busy changing frequencies and doing the checklist, when they looked up the other aircraft was crossing 300' above and about 700' out
118. LRG	Aircraft landed without clearance	Making a coupled approach for an autoland, doing checklists, fatigue, forgot to shift frequencies
119. LTT	Aircraft crossed an active runway after instructed to hold short	Copilot got instructions, assumed captain had them, started to do the checklist heads down and didn't catch the crossing, poor crew coordination
120. MLG	Aircraft filled with smoke at 37,000', declared an emergency and landed short of destination	Used appropriate checklists and procedures
121. WDB	Partial runway incursion, caused a go-around	Crew busy doing checklist, misunderstood clearance to taxi up to and hold short, taxied beyond the hold short point
122. WDB	Deviation from assigned SID	During taxi aircraft received runway changes, changed SID in FMS, runway reassigned, in doing the checklist and other duties, SID didn't get changed again
123. MDT	Altitude overshoot on climbout	Crew busy dodging thunderstorms on departure, changing frequencies, flying the aircraft, doing checklist, no altitude warning on the MDT when Capt. had been flying an airplane that had one
124. MLG	Aircraft had abnormal lights prior to V1, continued T/O, had engine fire warning at V2, lights went out and they continued to destination	Poor procedures, did an abnormal checklist for an air conditioning supply temp high, when maintenance checked the aircraft they found a 1" hole in the engine where the starter had reengaged
125. WDB	Engine disintegrated at about V1, crew aborted, residual fire put out by emergency crew	Crew followed proper procedure and used appropriate checklists
126. MLG	Engine not shut down prior to exiting aircraft	Stressful flight, stress resulting from merger, poor crew coordination, lack of use of checklist

AIRCRAFT TYPE	OCCURRENCE	CAUSE
127. WDB	Inaccurate navigation, deviation from assigned track	FMS programmed improperly, should have been caught on review of programming for checklist
128. MLG	Altitude overshoot during descent	Crew busy handling communications with company and ATC, doing PA announcements, running checklists, set wrong altitude into the altitude reminder
129. WDB	Both engines shut down at 1500' in climb, restarted and continued flight	Capt. did not use the checklist for an abnormal annunciator light, used the wrong switches to solve the problem, no crew coordination
130. WDB	Altitude overshoot during approach	Controller cleared the aircraft to 3000', thought he had cleared them to 4000', they got busy doing checklists and other duties and descended to 2600'
131. MLG	Engine failure in cruise, declared emergency, landed at the nearest suitable airport	Shutdown due to high EGT and low EPR, used appropriate checklists
132. MLG	Cargo compartment fire, emergency not declared since aircraft was on final for landing, did declare an emergency on the ground with a passenger evacuation	Illegally shipped hazardous cargo, crew indicated that with a two-man crew in this type of situation, trying to fly the aircraft, do checklists and everything else, one person is "out of the loop" trying to get information on the problem and the other person is left to do everything else
133. WDB	Engine flame-out when throttles were retarded for descent	Proper checklists used including restart checklist, successful restart, problem caused by bad bleed valve which is in the process of modification fleetwide
134. WDB	Unable to control cabin altitude, descended to control	Engine start switch in the wrong position for pack operation, should have been caught on the after starting checklist
135. MLG	Aircraft departed with incorrect fuel load, had to make a fuel stop	During predeparture checklists the crew was distracted by on board FAA inspectors, didn't check fuel properly

APPENDIX D

Form and Results of ALPA Survey

CHECKLIST SURVEY (95 returns for 80 mailed)

The reasons for the survey are fivefold. Each reason will have its own set of questions. The reasons are as follows:

1) Identify layout and other design characteristics of checklists that inhibit or promote easy use;

2) Determine what aspects of flight operations interfere with checklist use, and identify the phases of flight during which these distractions are most likely to occur;

3) Determine the degree to which checklist procedures are defined in the pilot handbook;

4) Identify variations in checklist use that can be attributed to crewmember characteristics;

5) Identify procedures or design changes that could be used to promote error-free checklist use.

1. LAYOUT AND DESIGN OF CHECKLISTS

1.1 Types of checklists you have used (please check types used and circle type currently used)...

	currently used	
a. Paper checklist	25	Yes 74 No 21
b. Laminated card(s)	52	Yes 82 No 13
c. Electronic (CRT)	1	Yes 8 No 86
• Does the display replace another display, such as weather radar		Yes 4 No 1
d. Mechanical scroll	1	Yes 23 No 62
e. Mechanical pointer		Yes 8 No 85
f. Mechanical slide		Yes 8 No 86
g. Toggle switch/annunciator light combination		Yes 0 No 91
h. Have you used, or do you now use, a mix of the above (i.e., - paper checklist & mechanical slide)		Yes 19 No 74
• If "yes," are the "normal" checklists segregated from the "emergency" and "abnormal" lists		Yes 16 No 6

(please explain in what way)_____

_____

i. Do you see an advantage to a mix of checklist types? Yes 11 No 77

(please explain)_____

1.2 Does the "silent" checklist have a place in airline cockpits? Yes 71 No 23

1.3 Of the following checklists, which do you feel should be "challenge/response" and which should be "silent"?

	challenge/response	silent
• Airplane acceptance	32	38
• Before start	71	5
• Before taxi	61	15
• Before takeoff	76	0
• Climb	16	60
• Cruise	12	64
• Descent/In range	43	33
• Before landing	73	3
• After landing	21	55
• Securing	51	24

1.4 The following questions pertain only to those who have used electronic (CRT) checklists and paper checklists and will attempt to ascertain the relative advantages and disadvantages of the two types. Please circle the appropriate answer.

a. Easier to use in all conditions of cockpit illumination	6 CRT	paper 0
b. Greater susceptibility to skipping items	1 CRT	paper 5
c. Easier to get at and use	5 CRT	paper 1
d. Ease of use in different operating conditions		
• Stationary on the ground	5 CRT	paper 1
• Moving on the ground	5 CRT	paper 1
• Airborne	5 CRT	paper 1
e. More heads-down time required	3 CRT	paper 2
f. Quicker to use	5 CRT	paper 1
g. If items are skipped and returned to (such as in taxiing without all engines operating), which is easier to use?	4 CRT	paper 2

1.5 If a checklist response is written "as required" do you answer with

a. A known value (i.e. - flaps...15°)?	Yes 83	No 5
b. "As required"?	Yes 15	No 72

1.6 Please indicate your feelings on the design of checklists you currently use.

a. List is too long	Yes 19	No 69
b. List doesn't cover enough	Yes 10	No 76
c. Print is too small	Yes 5	No 84
d. Easy to skip items unintentionally	Yes 35	No 54
e. Dimensions of list are too large	Yes 10	No 78
f. Convenient to use	Yes 70	No 16
g. Easy to use at night	Yes 58	No 31
• Is there sufficient supplementary lighting to make it readily visible?	Yes 67	No 14
h. Organized in a manner that promotes a smooth flow pattern	Yes 70	No 20
i. Organized in a manner that reflects standard operating procedure for the company	Yes 86	No 3
j. Convenient place to stow the lists	Yes 73	No 17
k. Easy to locate "emergency" lists when needed	Yes 56	No 31
l. Do you feel that the checklist workload is equally distributed among all crewmembers?	Yes 70	No 19
m. Any other comments_____		

_____

2. INTERRUPTIONS TO CHECKLIST USE

2.1 Please indicate on a scale of 1 to 10 (with 10 being the highest), which of the following activities tend most to disrupt good checklist procedures. If they are particularly disruptive at one or another phase of operation, please indicate at which phase(s) - (i.e., ground, climb, cruise, descent, or approach and landing).

	(RANK) score	phase(s)
a. Ground personnel communications	5.05(2)	_____
b. Company radio	3.06(7)	_____
c. Flight attendant requests	4.4 (3)	_____
d. ATC communications	5.4 (1)	_____
e. Crew conversations	2.4 (9)	_____
f. Navigation requirements	2.4 (9)	_____
g. External taxiing distractions	4.25(4)	_____
h. Configuring aircraft for departure	2.09(10)	_____
i. External inflight distractions	2.82(8)	_____
j. Configuring aircraft for approach	3.27(6)	_____
k. Aircraft abnormalities	4.06(5)	_____
l. Any others_____		

2.2 Do you feel there are times when the use of a checklist is disruptive to good operating procedures? Yes 37 No 58

(If "Yes," please explain)_____

_____

2.3 What percent of the time is the "Sterile Cockpit" concept, below 10,000 ft., adhered to by your airline's crews?

a. 100% of the time 21
b. 75% of the time 48
c. 50% of the time 16
d. less than 50% of the time 10

3. DEGREE TO WHICH PROCEDURES ARE DEFINED IN PILOT HANDBOOKS

3.1 Is a standardized method for the use of checklists spelled out in your company operating manual? Yes 88 No 6

3.2 If so, do most of the crews adhere to the prescribed method? Yes 85 No 7

3.3 Do you think the prescribed method could be improved upon? Yes 42 No 44

- How?_____

_____

4. VARIATIONS IN CHECKLIST USE ATTRIBUTABLE TO CREWMEMBER CHARACTERISTICS

4.1 Do the individual crewmembers have any influence on the manner in which a checklist is performed? Yes 69 No 26

4.2 If so, does this result in variations, from one crew to another, in the way in which the checklists are performed? Yes 52 No 34

4.3 Does the influence of the individual crewmembers sometimes result in the checklists not being performed, or being performed in other than the prescribed manner? Yes 41 No 53

4.4 Any comments_____

_____

5. IDENTIFY PROCEDURES OR CHANGES THAT MIGHT PROMOTE BETTER CHECKLIST USE

5.1 Do you have a personal "must check" list that you check regardless of how the formal checklists are accomplished (such as the old "GUMP" list)? Yes 65 No 29

- When do you use it?_____

5.2 Do you feel this sort of list would be useful to all front-end crews? Yes 44 No 42

5.3 Do you have specific checklists to cover undone items (such as for starting engines after a single-engine taxi)? Yes 25 No 69

5.4 If 5.3 is "No," what do you use for memory jogs to assure completion of checklist items?

- Coffee cup over the flap handle Yes 14 No 58
- Checklist between the throttles Yes 38 No 36
- Go through the list again Yes 46 No 28
- Other (please specify)_____

_____

5.5 Are your checklist procedures such that you find yourself reading checklists during periods of otherwise high workload (i.e., taxiing in ORD, given a runway change in the middle of a tight approach, etc.)? Yes 60 No 36

5.6 If 5.5 is "Yes," do you

- Stop the list until it becomes less busy? Yes 43 No 14 (some answered "yes" to both)
- Press on and hope that nothing gets missed? Yes 18 No 37

5.7 Do crews for the different aircraft types in your airline's inventory follow the same standard procedures for checklist use? Yes 86 No 5

- Under what conditions do they not?_____

_____

_____

6. THE FOLLOWING ARE SUGGESTIONS FOR POTENTIAL IMPROVEMENT IN CHECKLIST PROCEDURES AND USE Please check "Yes" or "No." Your added comments below each section would be helpful.

6.1 Create a core checklist, to be used industrywide, with variations by aircraft type and operating environment — Yes 39 No 53

6.2 Use of automated checklists wherever possible — Yes 44 No 31

6.3 No use of checklists on the ground when the aircraft is moving — Yes 27 No 68

6.4 Use of color coding for easy identification of checklists — Yes 77 No 15

6.5 On paper checklists, use larger print or better letter spacing, or both — Yes 69 No 23

6.6 Use a mechanical marker to mark checklist progress — Yes 34 No 55

7. If you have any suggestions or comments for improving checklist presentation, or a means of assuring that checklists are done in their entirety, please explain them.

_____

_____

_____

_____

8. BACKGROUND INFORMATION (Average data shown)

The following information will be used anonymously to help the survey team evaluate the data received.

8.1. Experience flying transport aircraft

a. Types 3.83
b. Hours in type _____
c. Seats flown _____

8.2 Experience flying other sophisticated aircraft

a. Types _____
b. Hours in type _____
c. Seats flown _____

8.3 Hours in each seat collectively

a. Captain 4140
b. First Officer 5570
c. Second Officer 2910 (of these, 22 had no 2nd officer time.)

8.4 Aircraft and seat currently flown _____

8.5 Age 45.78 (ranged from 31-66)

8.6 Sex Male 94 Female 1 (32 yr. old DC-9 Capt.)

8.7 Visual correction

a. None Yes___ No___
b. Nearsighted Yes___ No___
c. Farsighted Yes___ No___
d. Other _____

e. Do you use corrective lenses while flying Yes 36 No 51
- single focal Yes___ No___
- bifocal Yes___ No___
- trifocal Yes___ No___
- top-and-bottom focal Yes___ No___

8.8 Does your company have a specific policy on cockpit resource management? Yes 63 No 23

8.9 If so, do most of the Captains adhere to the policy? Yes 52 No 12

- If not, do they basically adhere to Captain's autonomy? Yes 32 No 3

THANK YOU FOR YOUR TIME

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